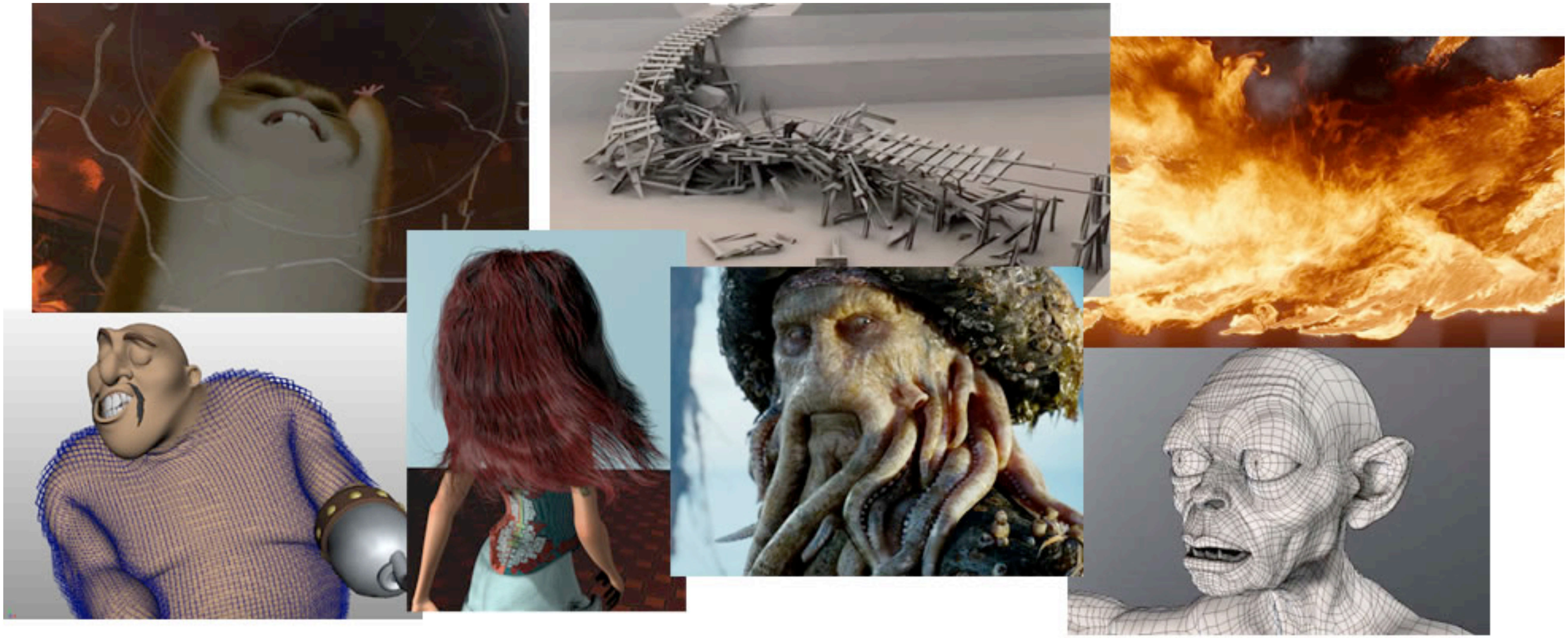

Welcome to CS839!
Topics In Computing:
Physics-based Modeling and Simulation

Fall 2019, 4:00-5:15 MWF

Today's lecture

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We will give a first opportunity for exposure to the class software infrastructure, and next lecture we will proceed directly to authoring/animation/visualization of dynamic solid geometry

What is possibly the objective of ...

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Computer Graphics : Making beautiful images

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Simulation & Modeling : Create (dynamic) content which can be rendered into beautiful images

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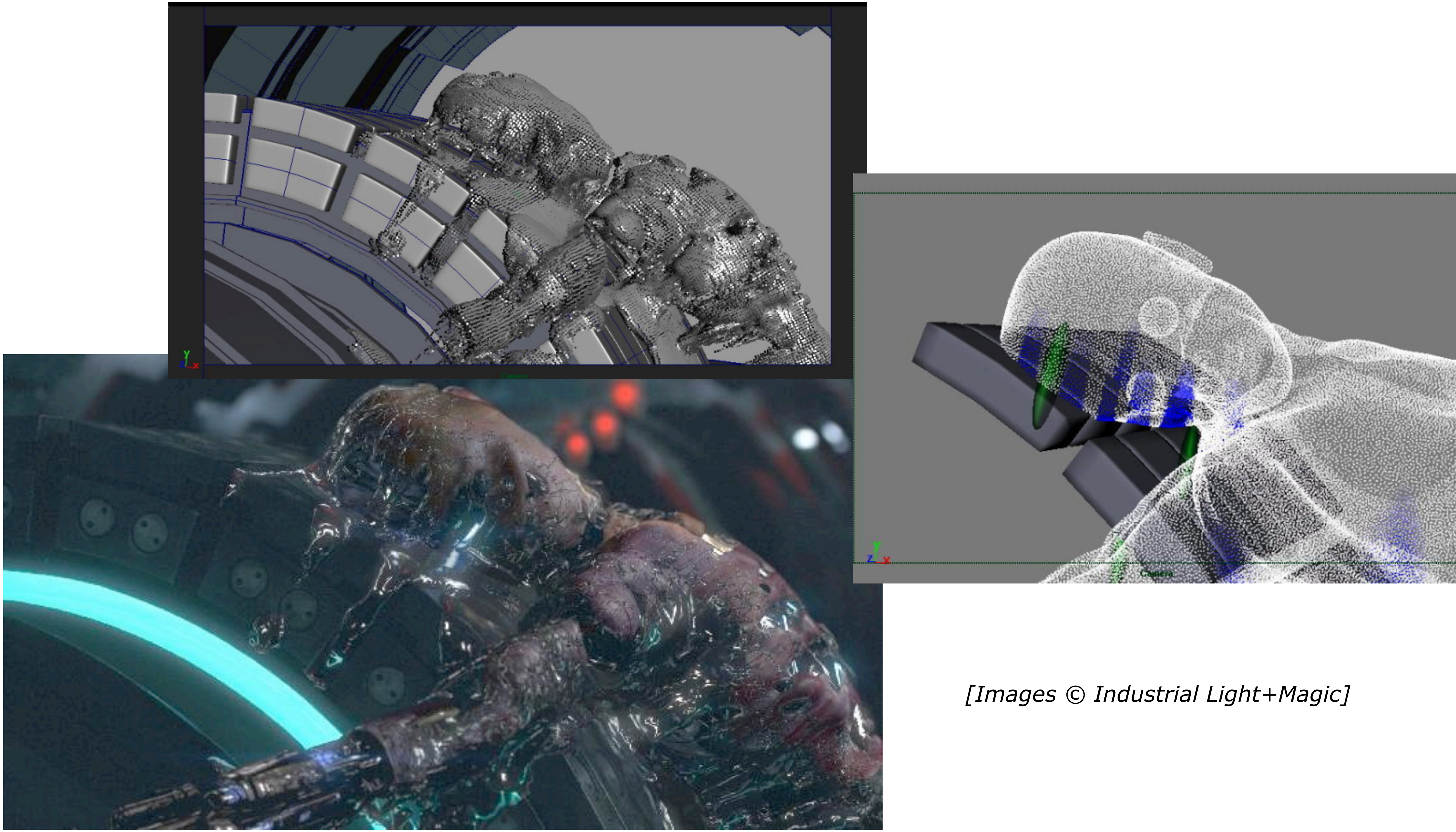
Simulation & Modeling : Create (dynamic) content which can be rendered into beautiful images

... and why use simulation?

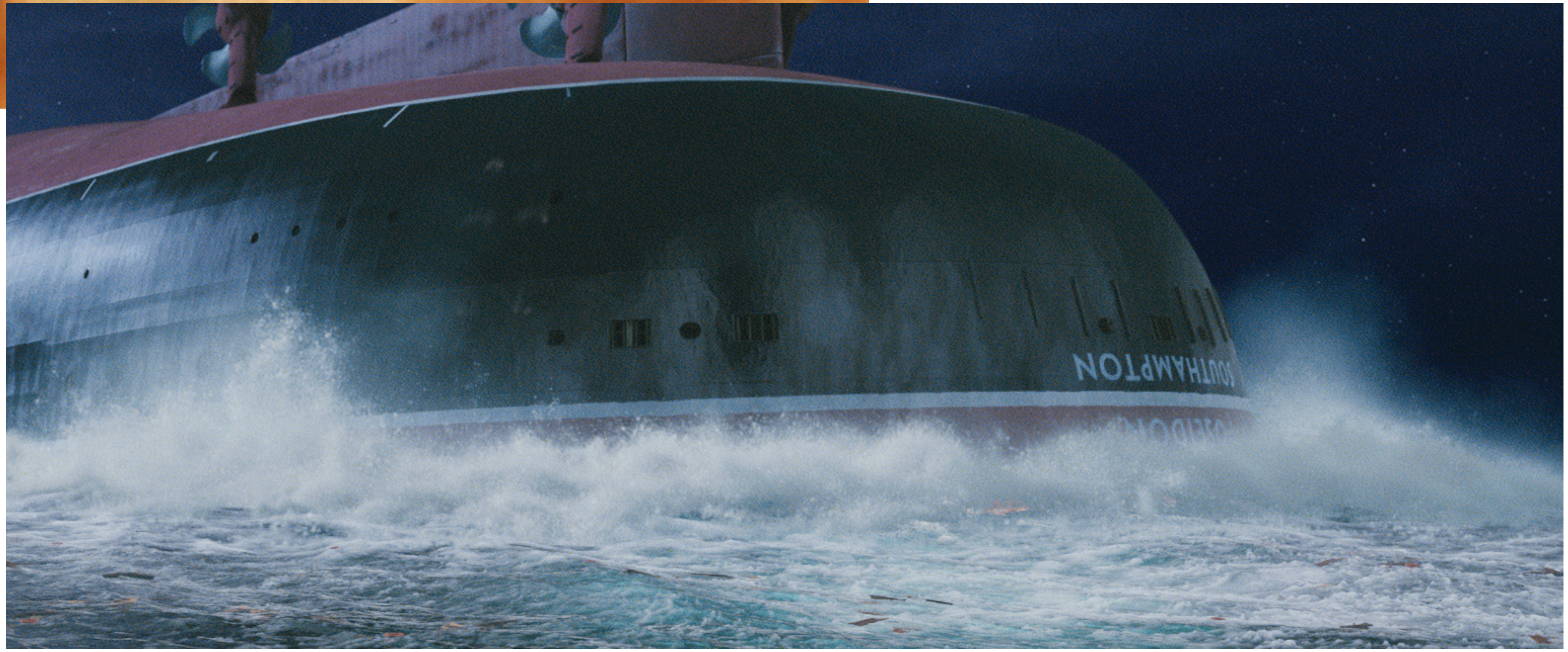


[Images © Industrial Light+Magic]

Motivation : Fictional objects, exotic materials

[Images © Industrial Light+Magic]

Motivation : Art-directable "natural" phenomena



[Images © Industrial Light+Magic]

Motivation : Scenarios that cannot be replicated with scaled models

[Credits: E. Parker, J. O'Brien, Pixelux Entertainment Videos © LucasArts Ltd.]

Motivation : Enhanced gameplay

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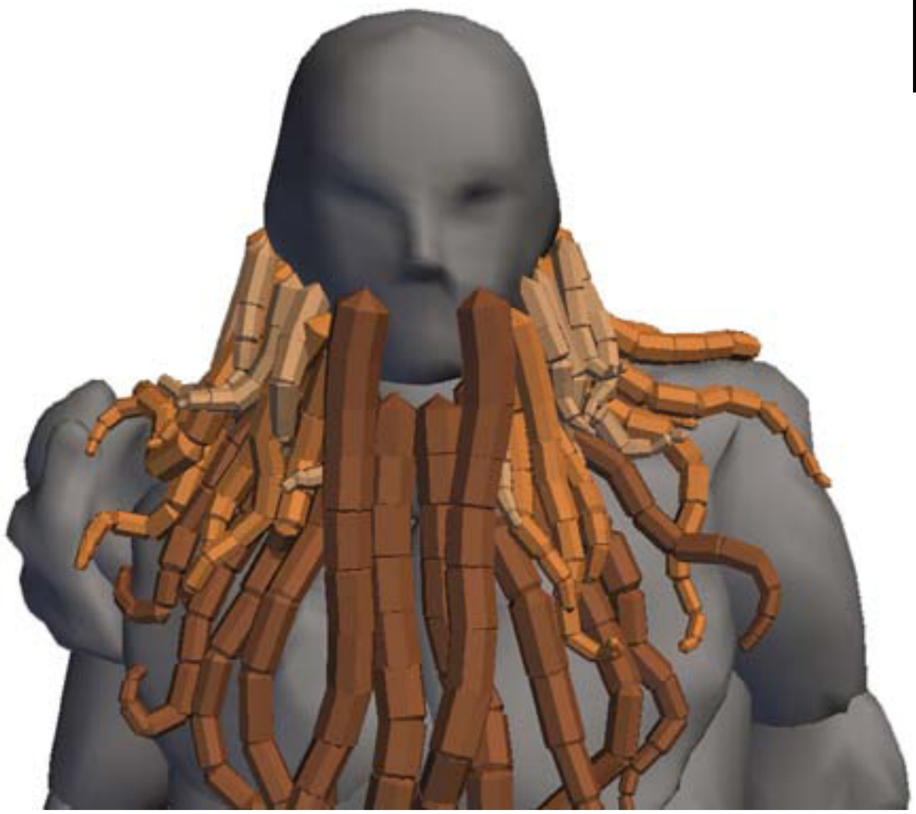
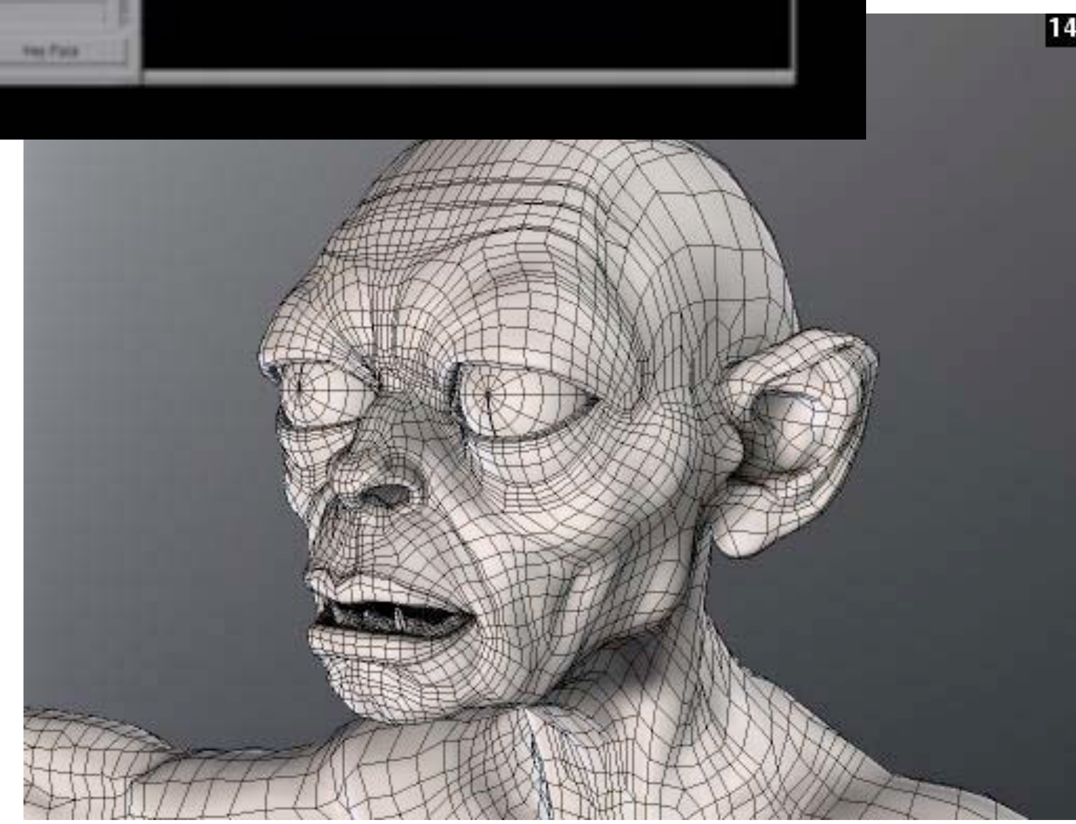
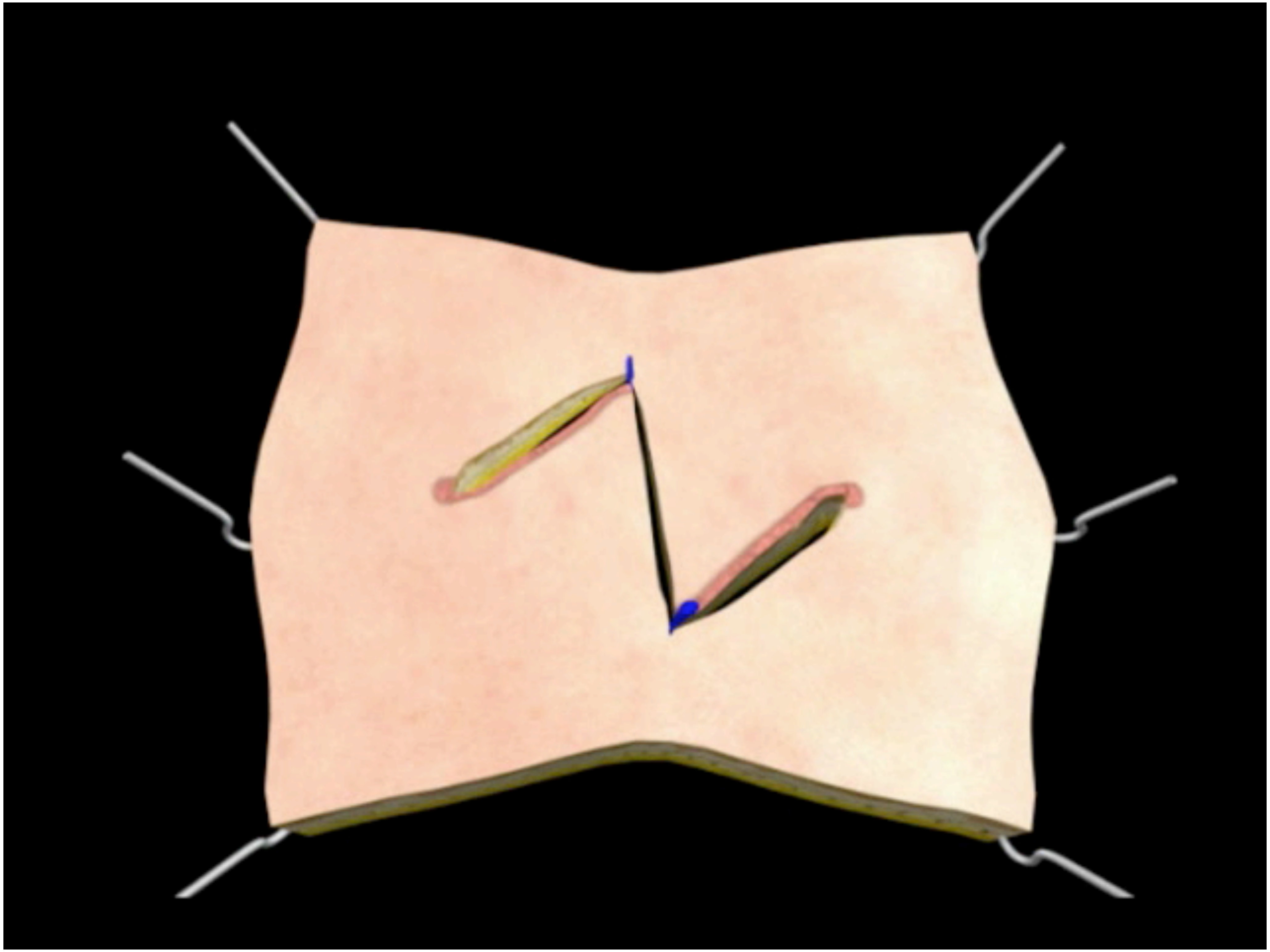


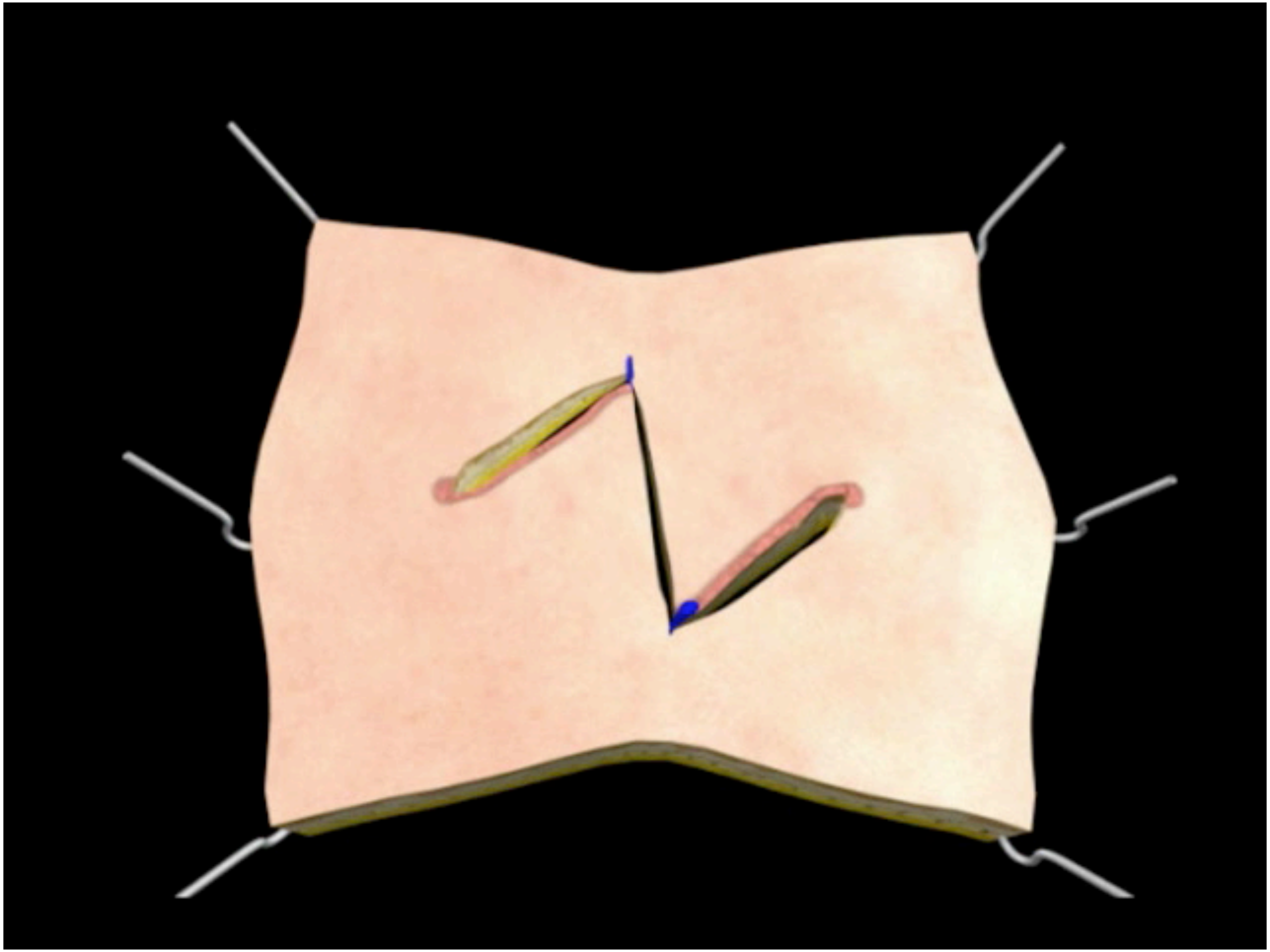


[Videos © Weta Digital, Industrial Light+Magic]

Motivation : Expressive fictional characters



Motivation : Virtual training environments



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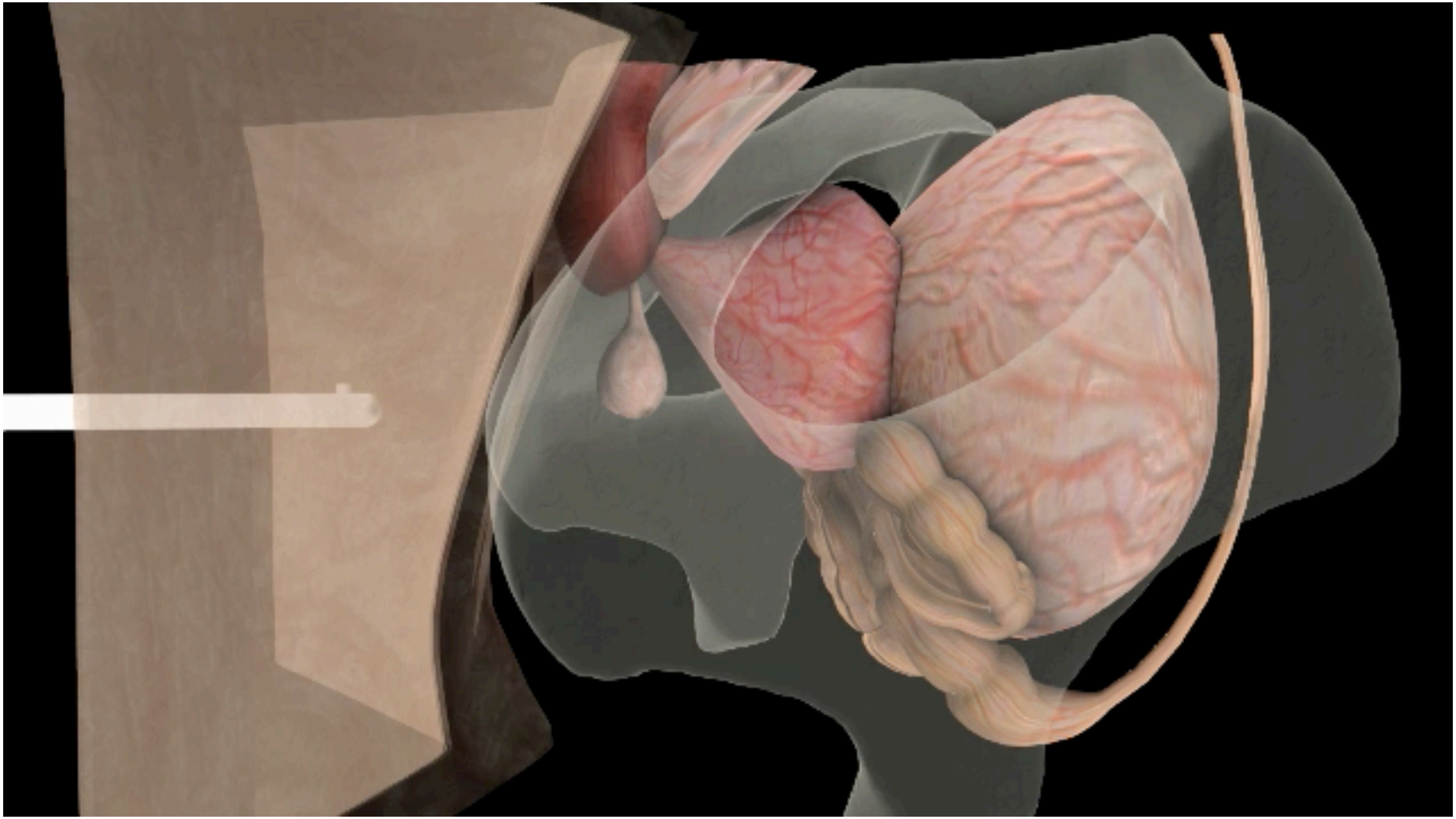

[Credits: Chentanez et al. “Interactive Simulation of Surgical Needle Insertion and Steering”, SIGGRAPH2009]

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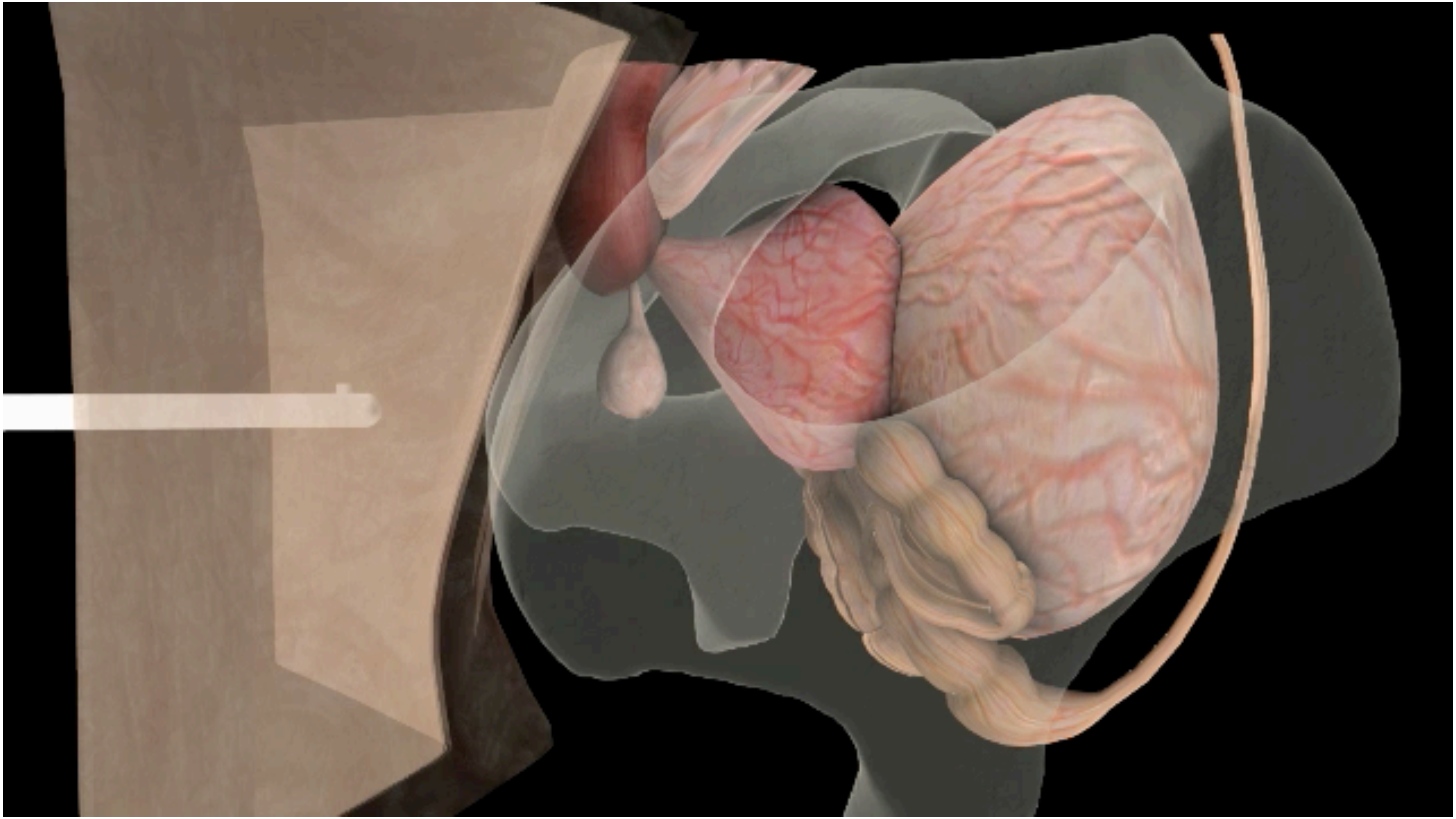

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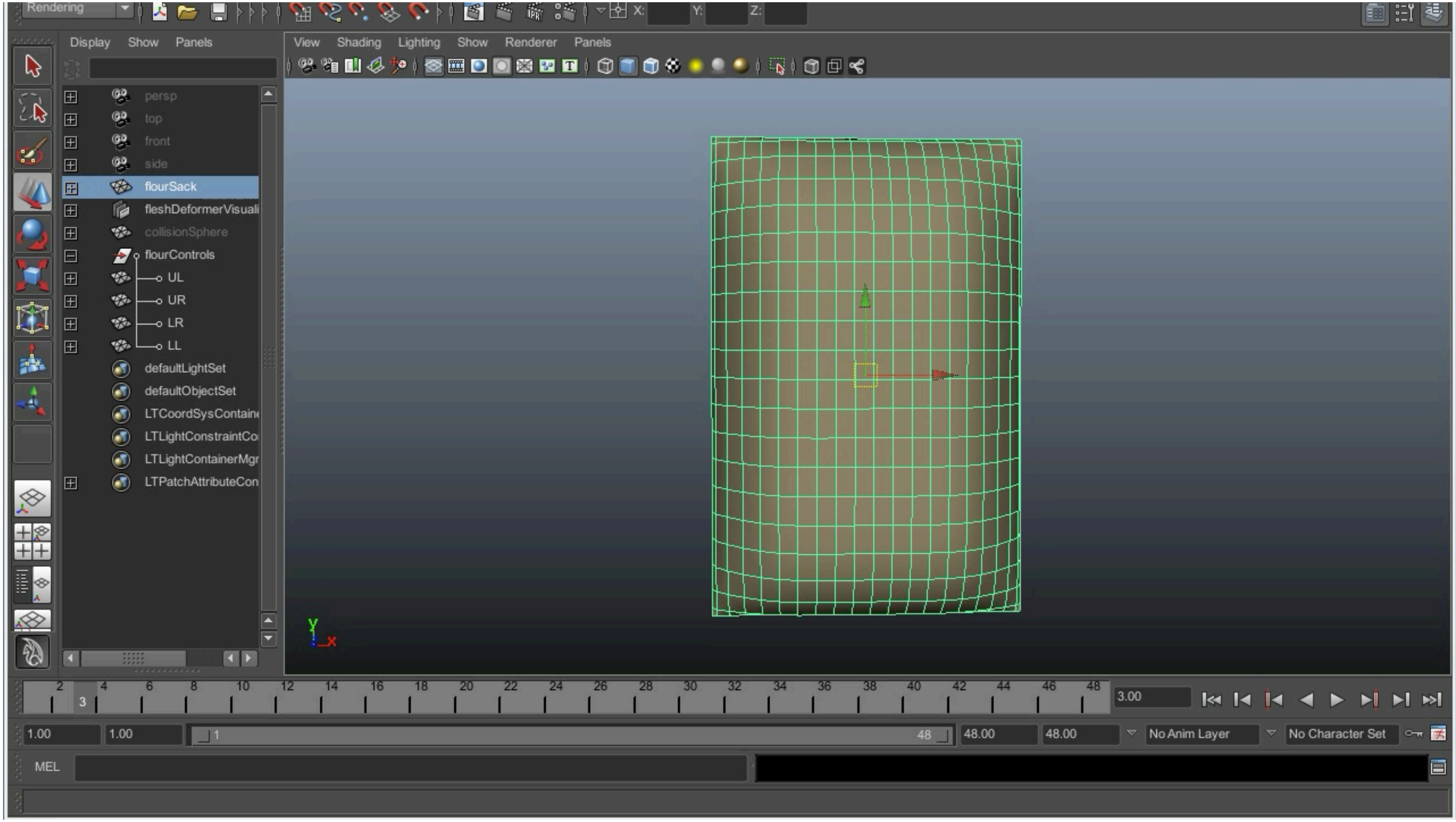
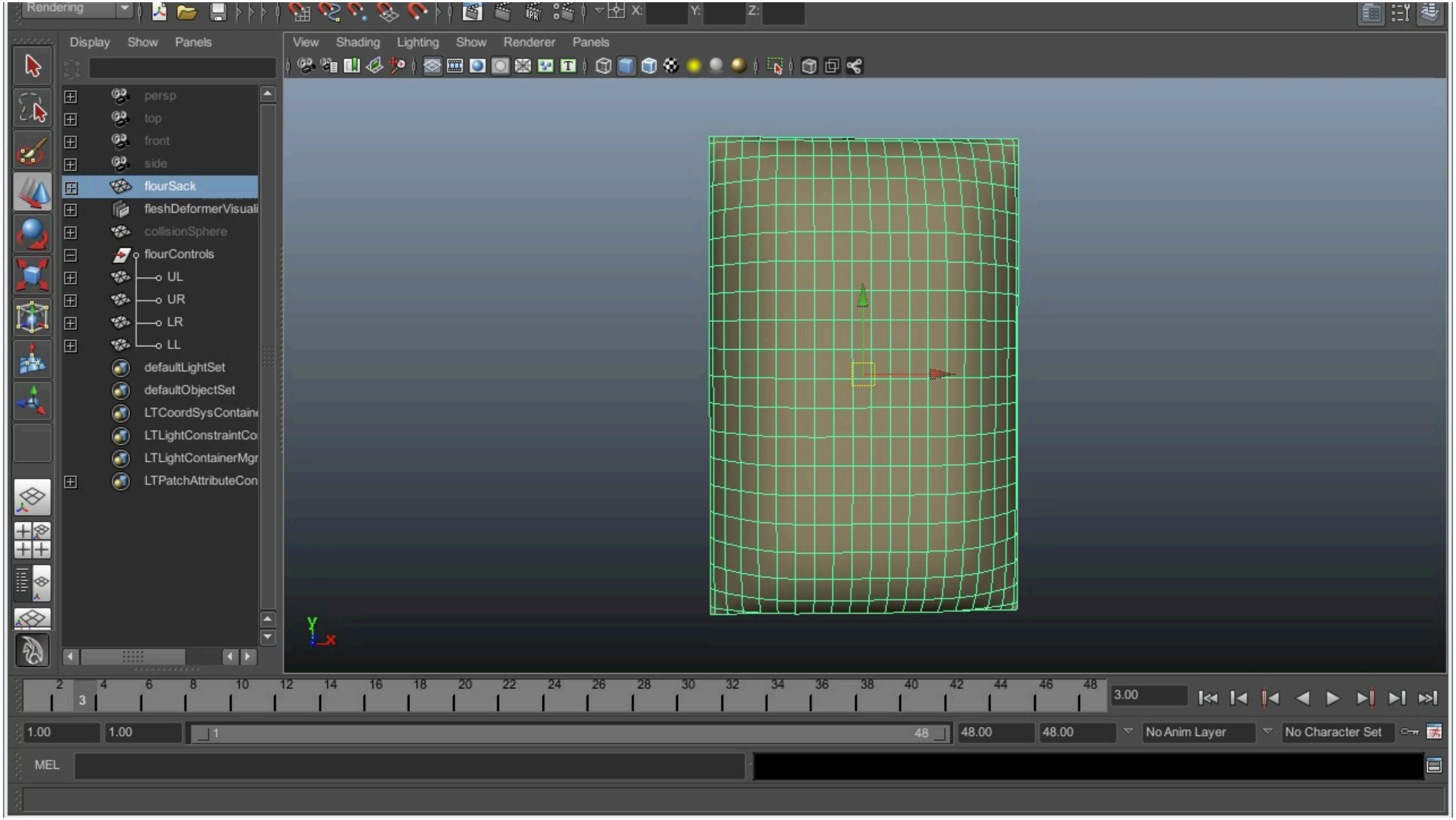


Augmentation of animation/modeling tools



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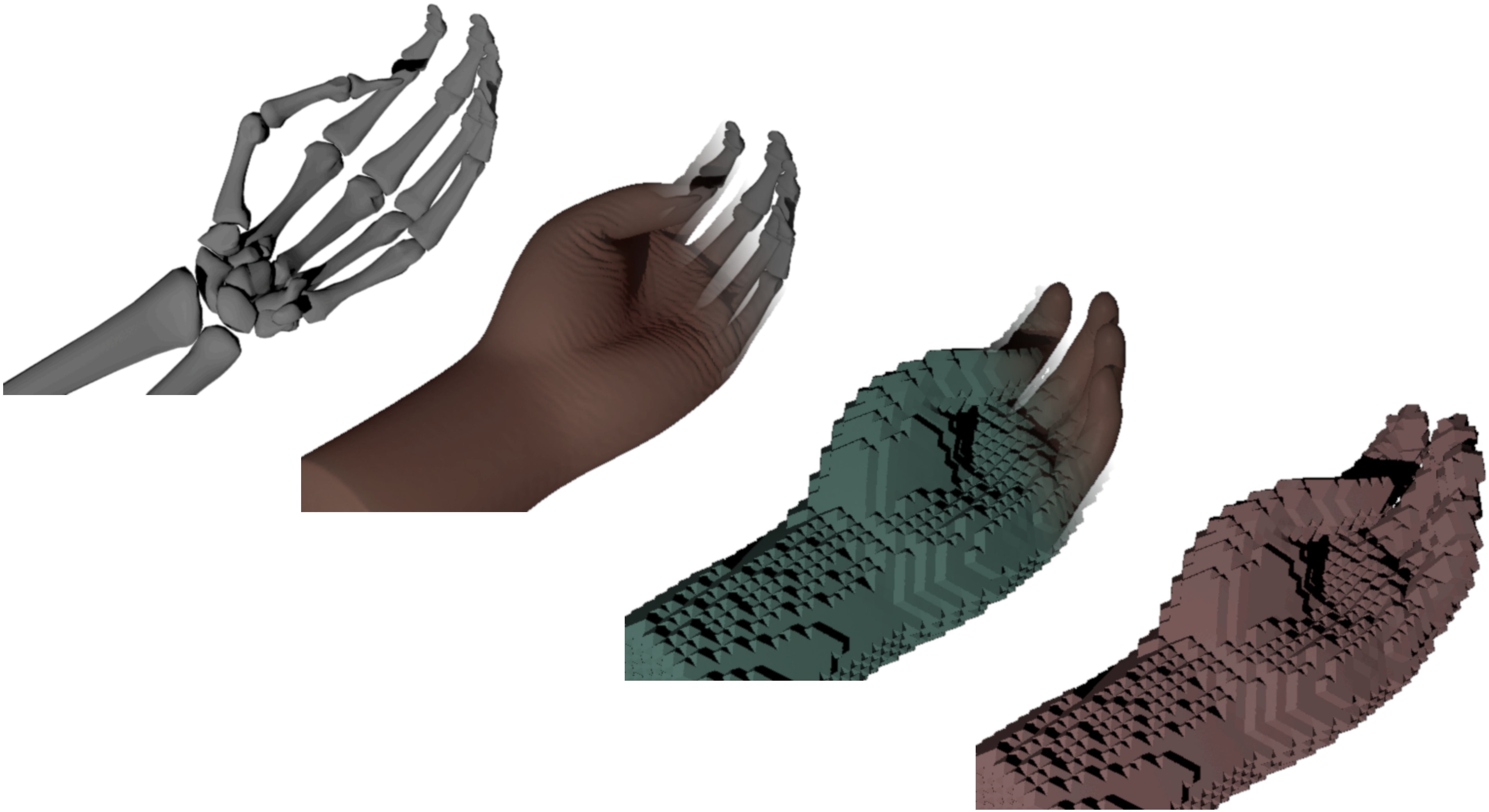

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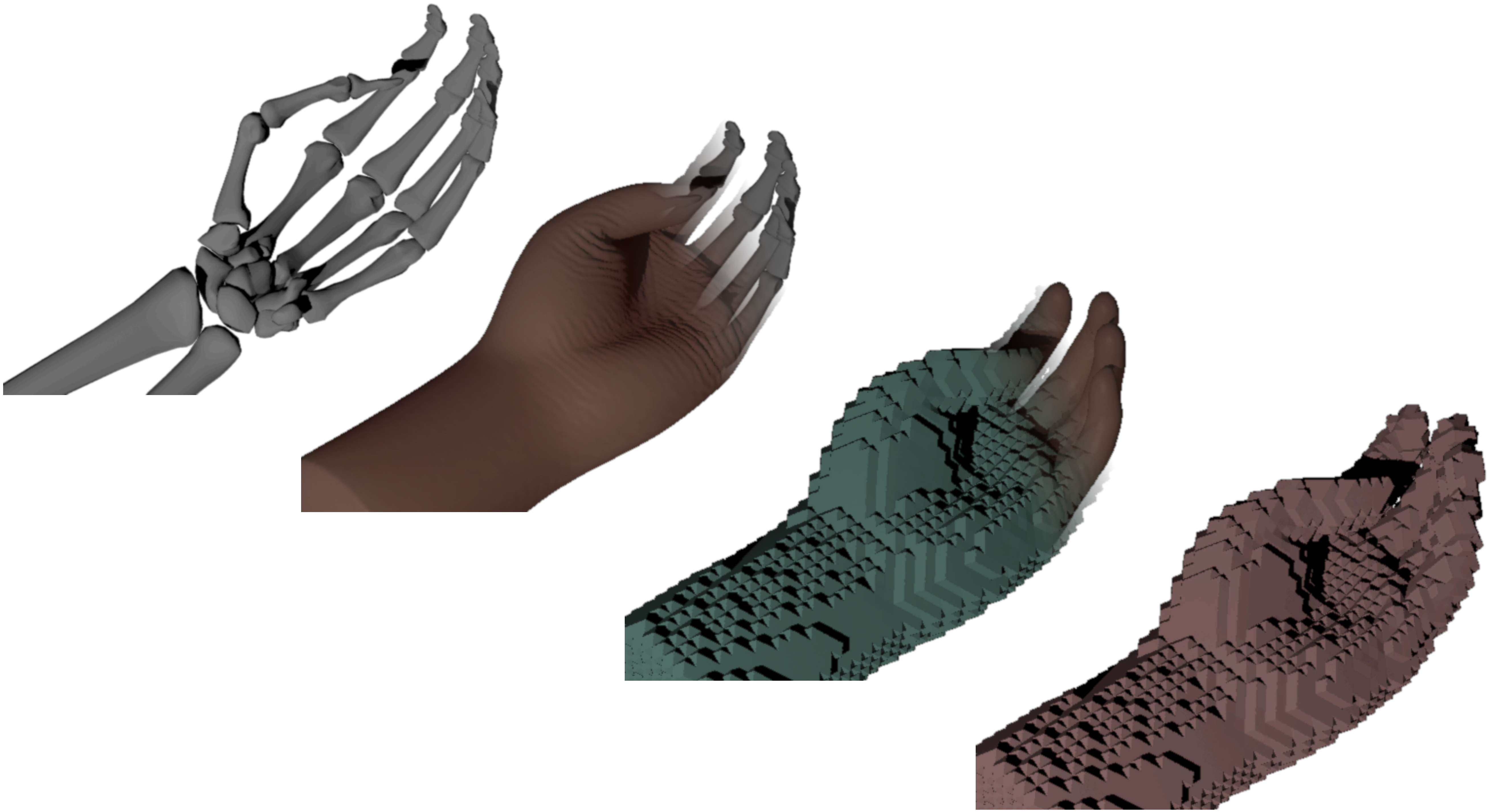

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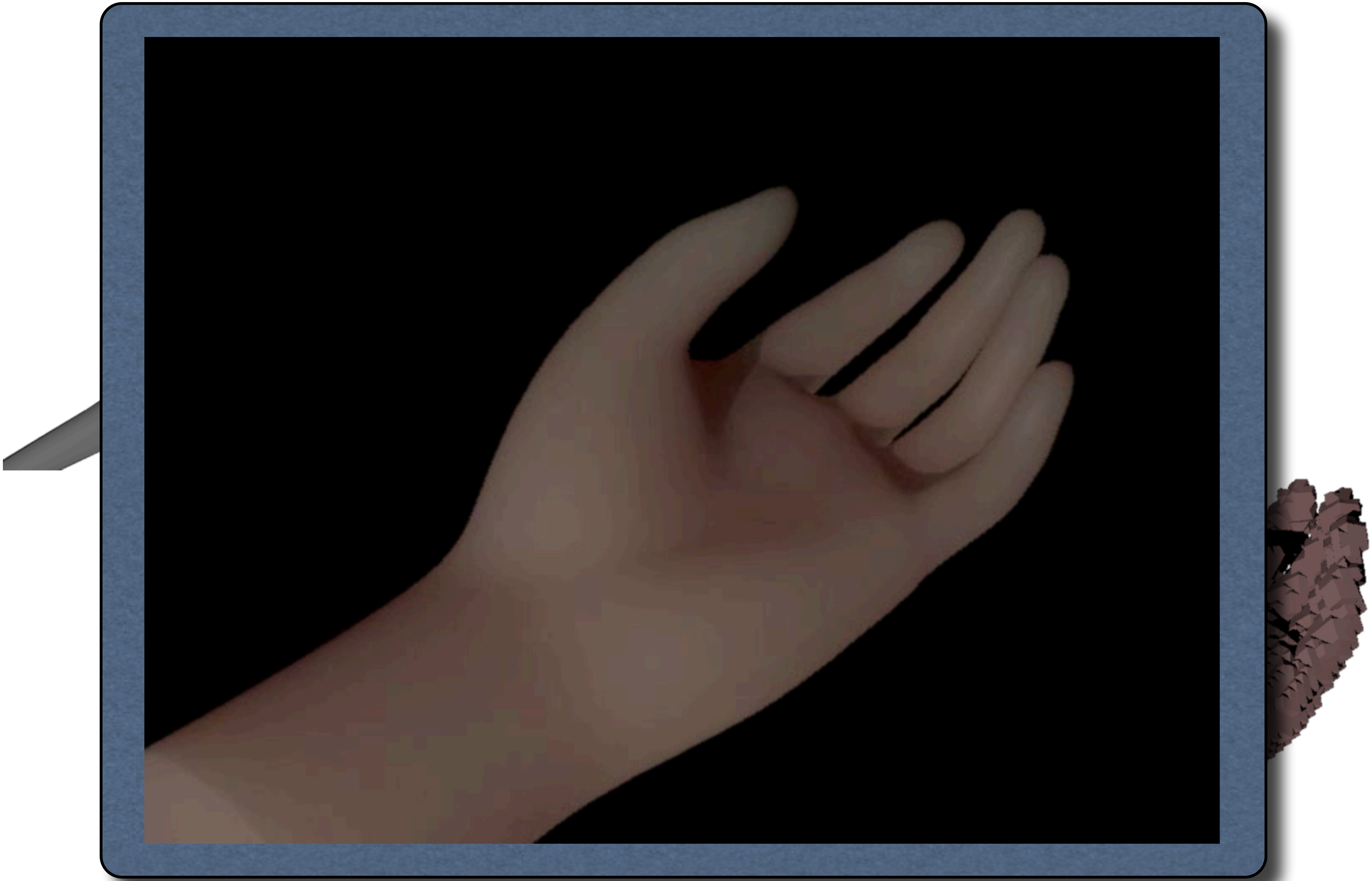

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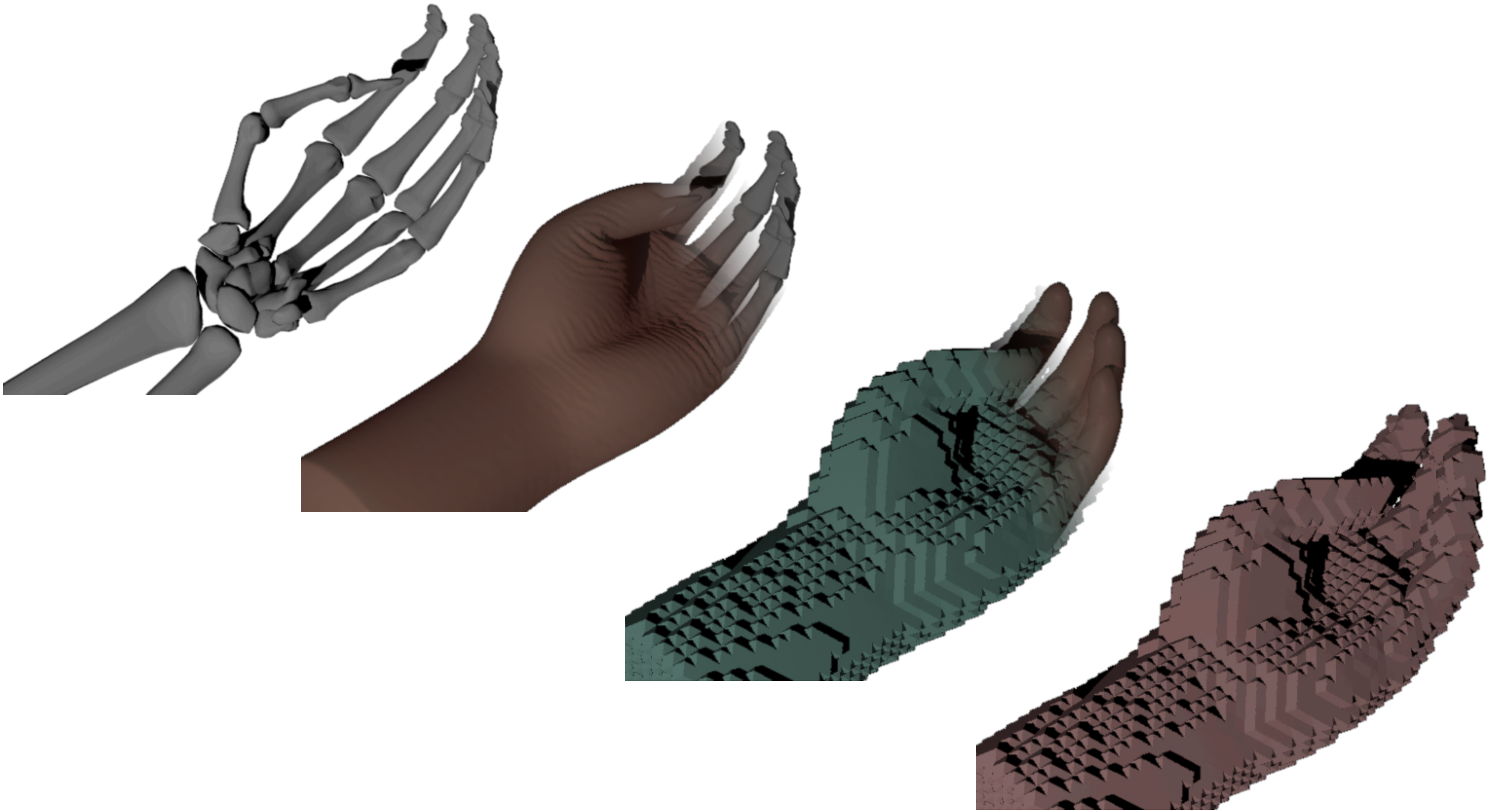

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Physics-based geometrical modeling

Physics-based geometrical modeling

Physics-based geometrical modeling (fracture)

- *Geometric modeling of fracture and material failure*
- *Crack propagation animation*

[Images © Disney]

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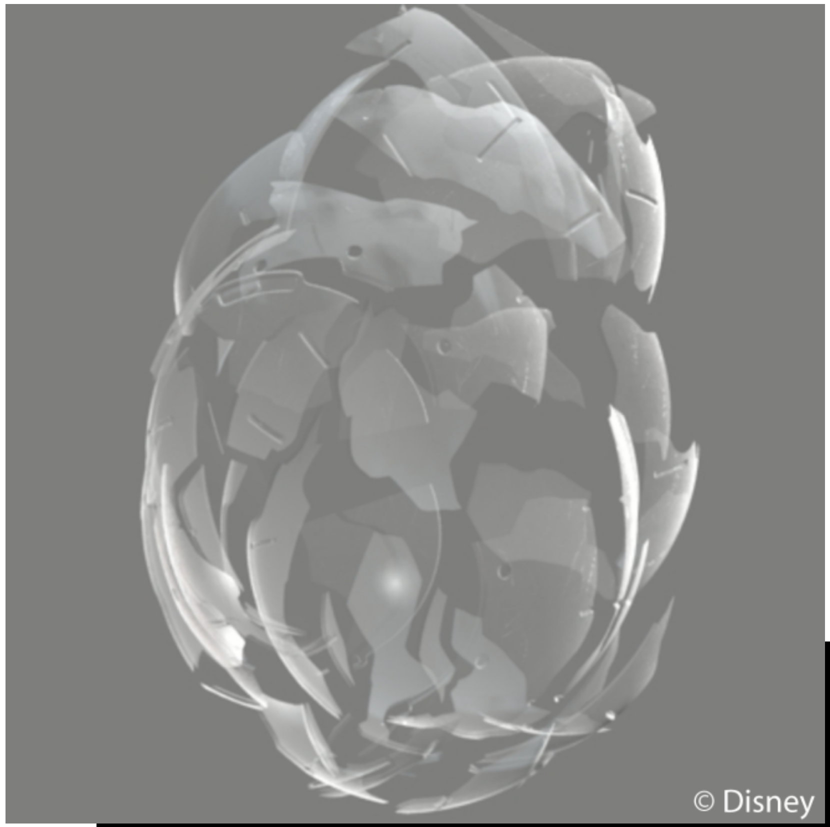

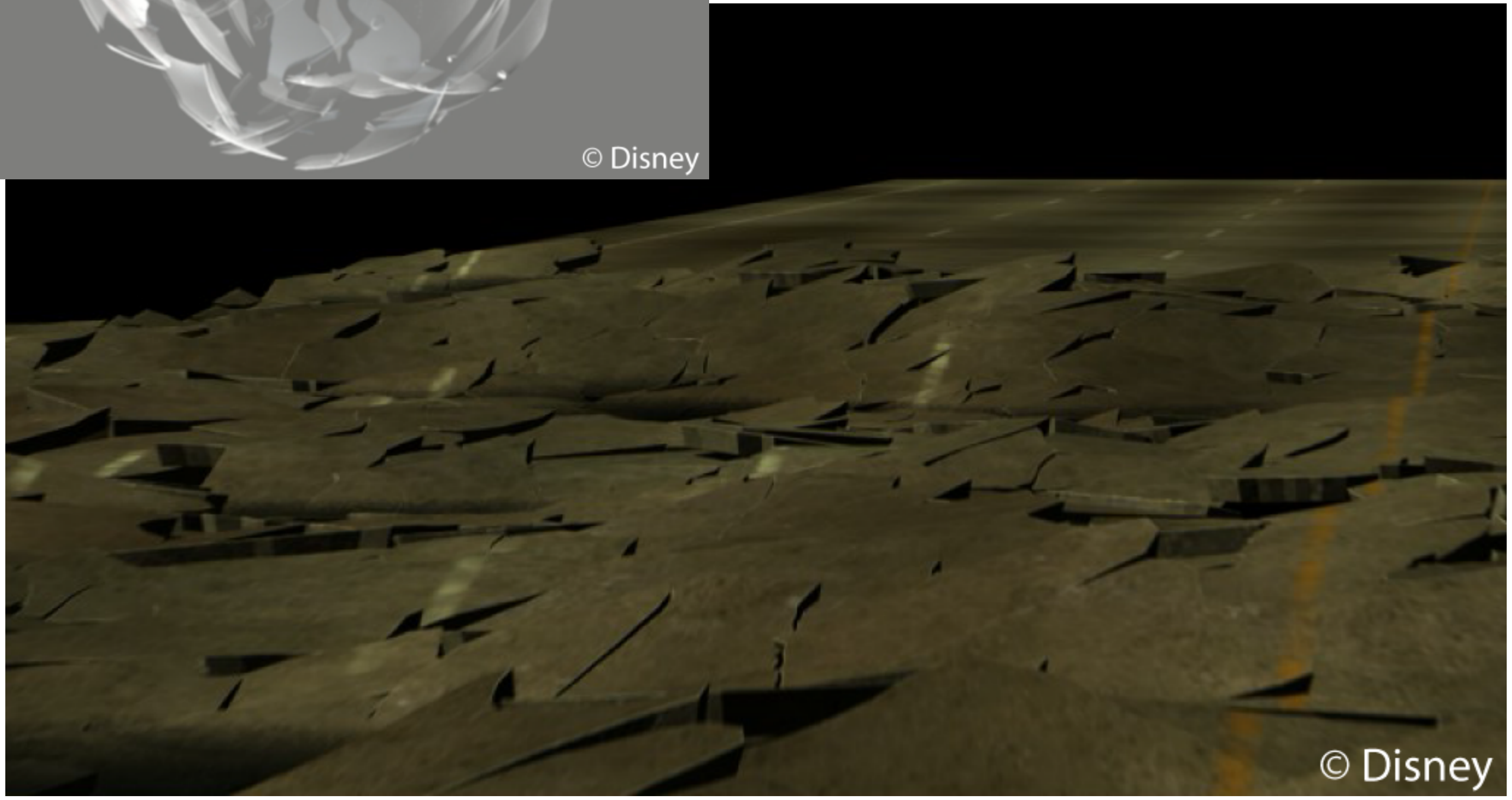

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[Images © Disney]

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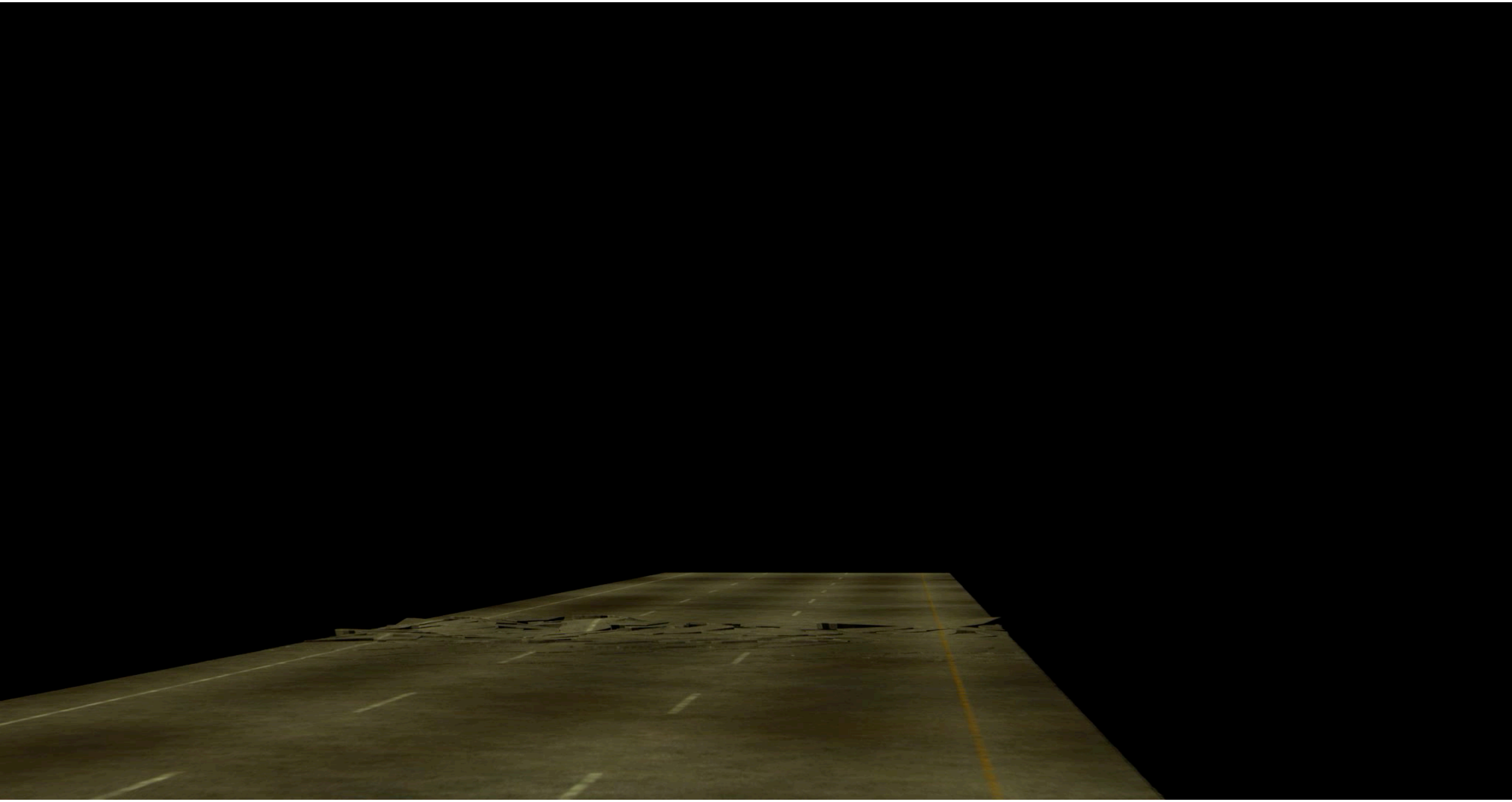

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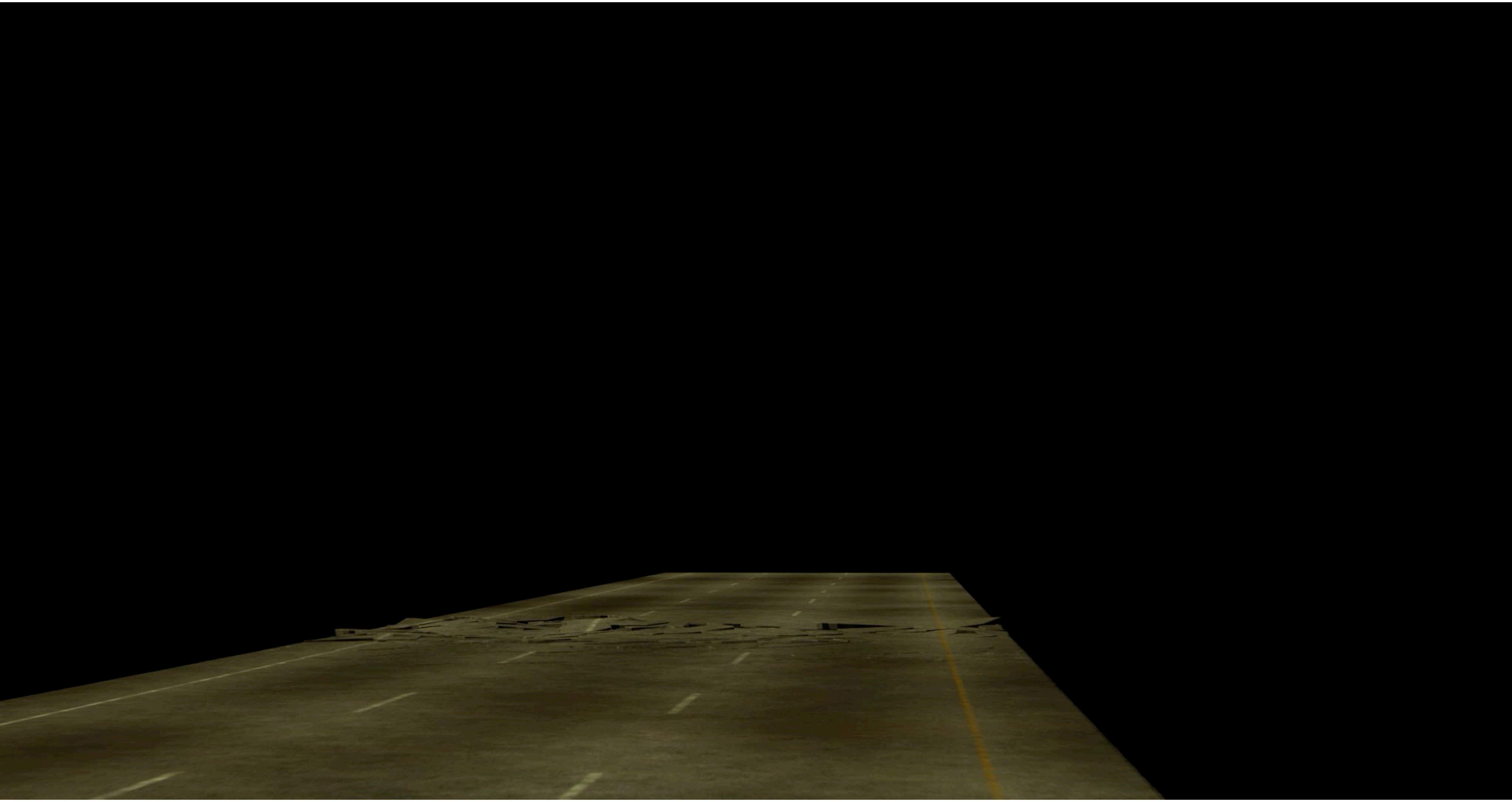

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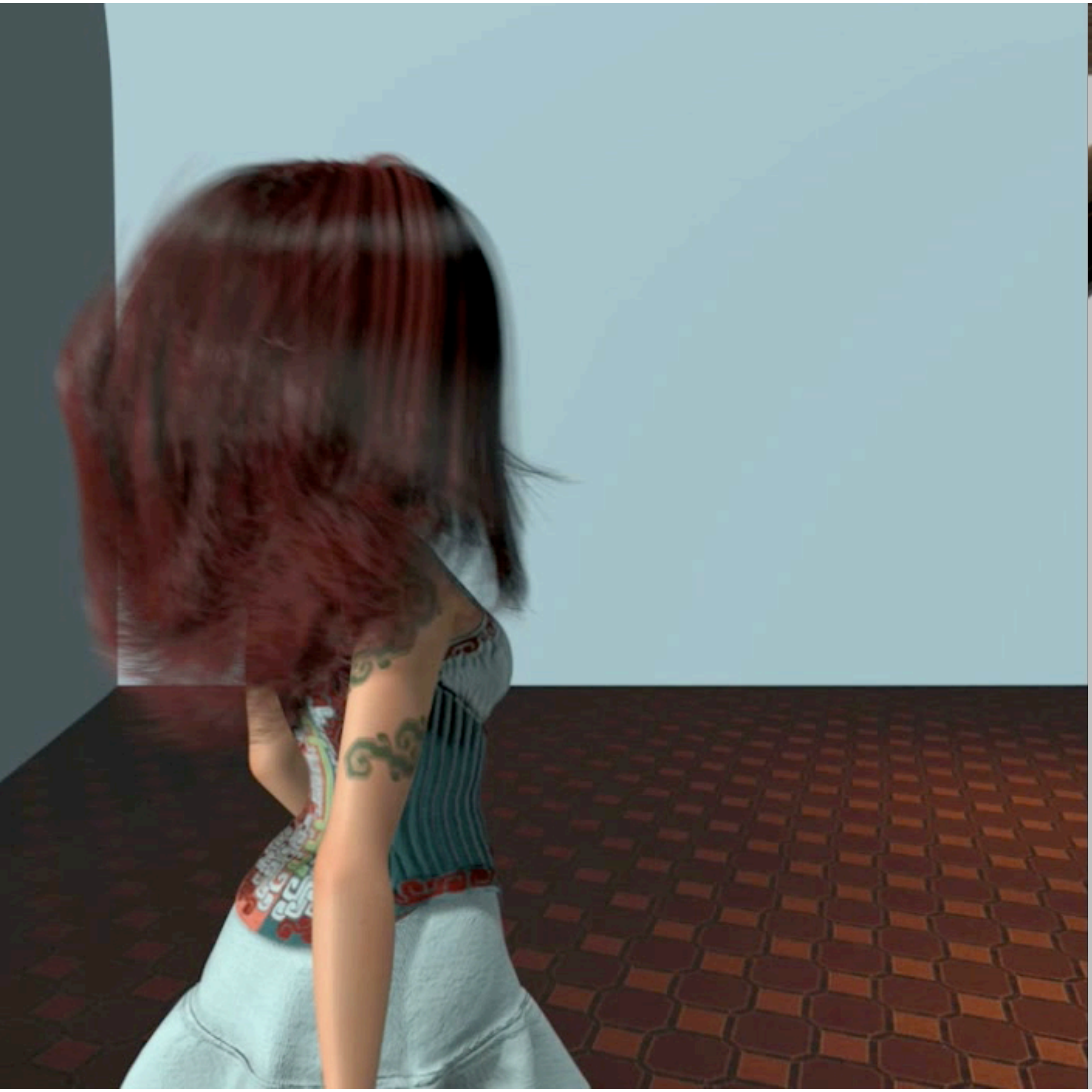
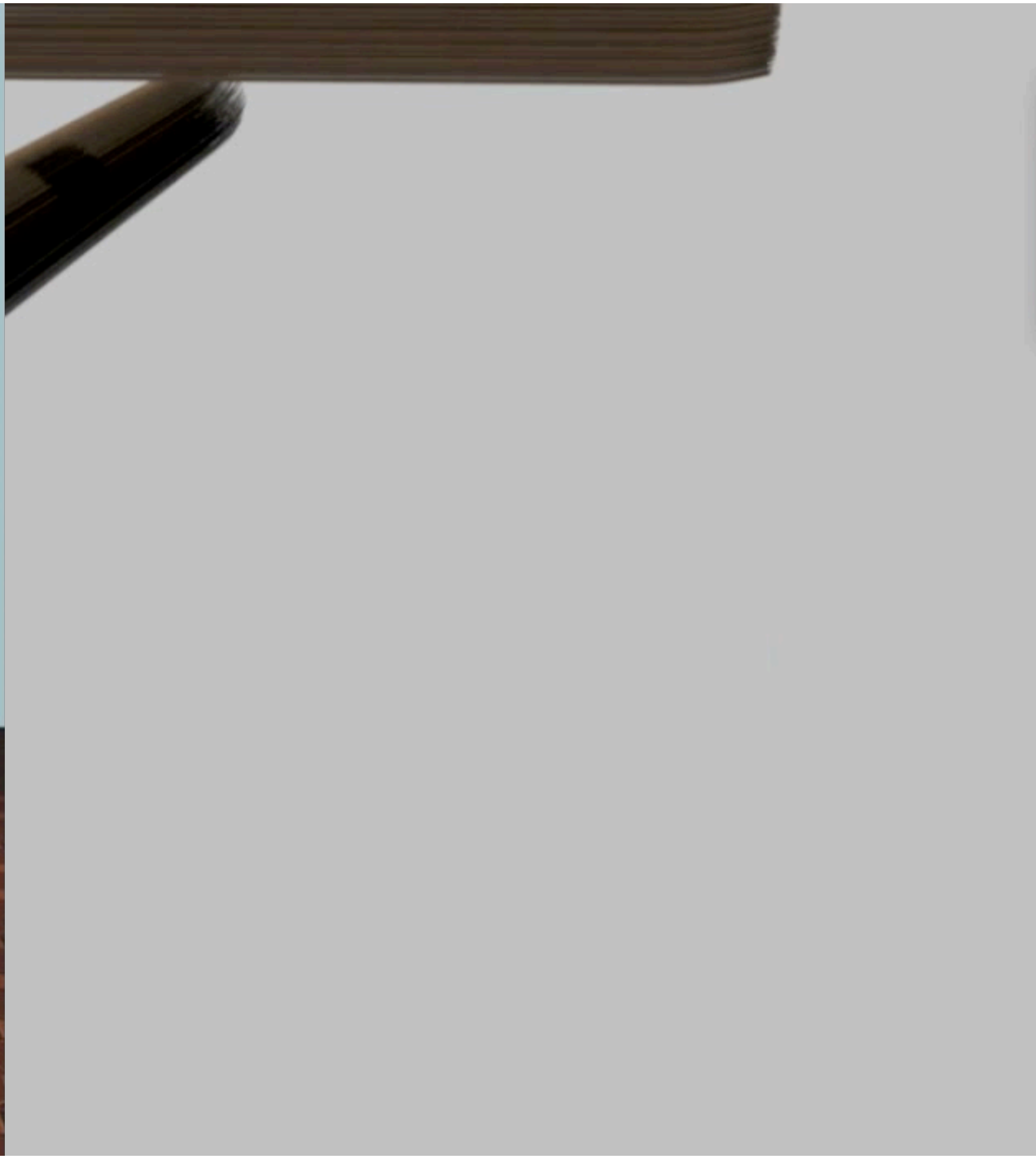
Physics-based geometrical modeling (hair)





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Course information

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- Website : http://pages.cs.wisc.edu/~sifakis/courses/cs839-f19
  - Check for lecture notes, assignments & reading materials

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- Email : sifakis@cs.wisc.edu
  - Please add "[CS839]" in the beginning of the subject line!
  - Email policy : Feel free to email as frequently as you need. Typically you will receive a response within 24hrs. However, be prepared to wait until next office hours (worst case) to get a comprehensive answer. If urgent, ask for an appointment.

Course information

- Objectives
  - Familiarize yourselves with the concepts and techniques of physics-based modeling and simulation
  - Obtain an understanding of available techniques, and know what papers to refer to for deeper insights and technical details
  - Acquire **hands-on** experience creating software for physics based simulation. Work with (often large) software libraries and implement reusable, efficient and well-structured code
  - Learn how to obtain information through literature search
  - Exercise your presentation skills

Evaluation

Evaluation

- Will be based on three components, with flexibility to adjust effort and emphasis between them
  - Attendance, Participation and Class Service
  - Regular (small scale) individual Programming Assignments
  - Larger scale class project (individual, or team upon approval)
- Expectation is that students will dedicate about 80hrs of effort outside of lectures during the semester, divided among these categories for an "AB" grade. Final grade based on effort and quality of work
- Substantial flexibility of allocation of effort, however ***at least half*** of effort should be dedicated to development/programming.

Evaluation

Evaluation

- Attendance, Participation and Class Service may include:
  - An optional 10-15min in-class presentation of a research paper
    - Must prepare PowerPoint/Keynote slides, which will be subsequently posted on course website
    - Topics in coordination with instructor
  - Scribing of theoretical class lectures (LaTeX or Keynote)
  - Participation in developing components of software infrastructure, beta-testing and troubleshooting
  - Prominent presence in Piazza discussions, having an active role in issue resolution with software infrastructure

Evaluation

Evaluation

- Individual (small scale) programming assignments
  - Primarily contained within the first half of the semester
  - Assignments will ask you to implement an established process, and familiarize yourselves with fundamental modeling and simulation techniques
  - Sample topics:
    - Author a procedural animation for a set of deformable bodies (e.g. parts of a virtual character, or various inanimate objects)
    - Implement a time integration scheme for simulating cloth or volumetric solids
    - Implement a simple collision detection and/or response algorithm

Evaluation

Evaluation

- Larger-scale class project
  - Either individual, or in groups of 2 (with your recommendation, and the instructor's consent)
  - Deliverable at end of semester
  - The goal of the project is to extend somewhat beyond what is a standard practice, and ideally experiment with an original idea.
  - Sample topics:
    - Accelerate the performance of a specific simulation, by using a more advanced or specialized algorithmic technique.
    - Model a nonstandard trait for a virtual material (e.g. viscoelasticity, anisotropy, surface tension)
    - Apply a known technique to an original application

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  - A basic knowledge of calculus and linear algebra is assumed (more details in next slides)
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  - You should be comfortable with C++ programming
  - You will need to study and use third-party libraries
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  - Experience with C++ templates will be useful (but not essential)
- Experience with parallel programming (threads, MPI, OpenMP, CUDA) is not required, but if you have it you are encouraged to pick projects that leverage this exposure.

Prerequisites (Computer Graphics)

You are expected to have working knowledge of:

- The general material of CS559 (Undergraduate Computer Graphics)
- More emphasis on geometry (Points, Polygons, Transforms) and associated mathematical concepts. Basic understanding of the graphics pipeline is a plus, although we would not need to intervene in shaders, textures and interactive graphics tricks all that much.
- Ask the instructor if you have doubts about your prior exposure, or concerned about the adequacy of your past experience.

Prerequisites (mathematical background)

You are expected to have working knowledge of:

- Vector valued functions, and functions of several variables
- Computing derivatives (and partial derivatives) of moderately complex functions, e.g.

$$\text{Find } \partial f/\partial x,\ \partial f/\partial y \text{ when } f(x,y) = \frac{x}{\sqrt{x^2+y^2}}$$

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But, we will review in class topics such as:

- Numerical approximations of derivatives and integrals
- Computing certain types of exotic derivatives, e.g.

$$\text{Find} \;\; f'(t) \; \text{when} \;\; f(t) = \det(\mathbf{A}+t\mathbf{B})$$

$$[\text{Answer: } f'(t) = \det(\mathbf{A}+t\mathbf{B}) \cdot \mathrm{tr}\{(\mathbf{A}+t\mathbf{B})^{-1}\mathbf{B}\}]$$

Prerequisites (mathematical background)

You are expected to have working knowledge of:

- What an n-dimensional vector and an nxn matrix is
- The concept of a trace and a determinant of a matrix
- The concept of eigenvalues and eigenvectors of a matrix
- Simple methods for solving linear systems of equations $\mathbf{A}\mathbf{x} = \mathbf{B}$ (for example, Gauss elimination)

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But, we will review in class topics such as:

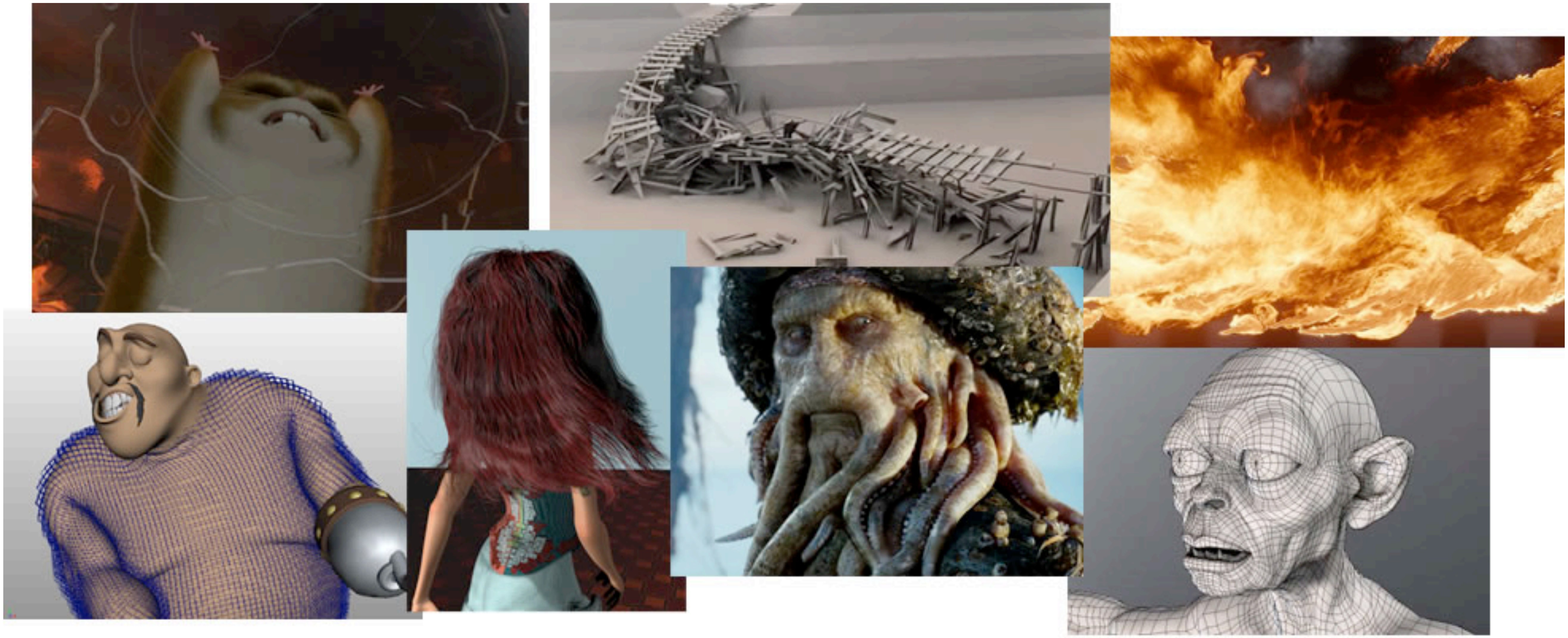
- How to solve linear systems of equations very efficiently (e.g. often at cost O(n) or O(nlogn), when considering n equations and n unknowns)
- Generalizations of matrices (2-dimensional arrays) to tensors (higher dimensional arrays)

Software infrastructure

- First half of class will heavily use the Pixar USD (Universal Scene Description) pipeline dynamic scene content
  - [Immediate Task] Obtain from :
    https://graphics.pixar.com/usd/docs/index.html
    https://github.com/PixarAnimationStudios/USD
  - You are welcome to use Linux, MacOS, or Windows
  - Make sure you can compile fully, including the visualization tool "usdview"
    (Try .usda files under USD/extras/usd/tutorials/*/, or http://pages.cs.wisc.edu/~sifakis/courses/cs839-f19/data/TestSimulation.usda)
  - Report issues on Piazza, as soon as possible
  - Extra office hours on USD set-up : Sept 5th 3:30-5:00pm

Software infrastructure

- We will use elements of the PhysBAM physics-based modeling library, mostly for prototyping purposes
  - Clone source from the GitHub (report access issues) https://github.com/uwgraphics/PhysicsBasedModeling-Core
  - Used at Walt Disney Animation studios, Pixar, Intel Corporation, Industrial Light+Magic
  - The version above has been recently retrofitted (at UW) for Linux&MacOS compatibility (tested on g++, icc, clang)
  - Includes much more than we will actively use
    - No dynamics; we shall implement those from scratch



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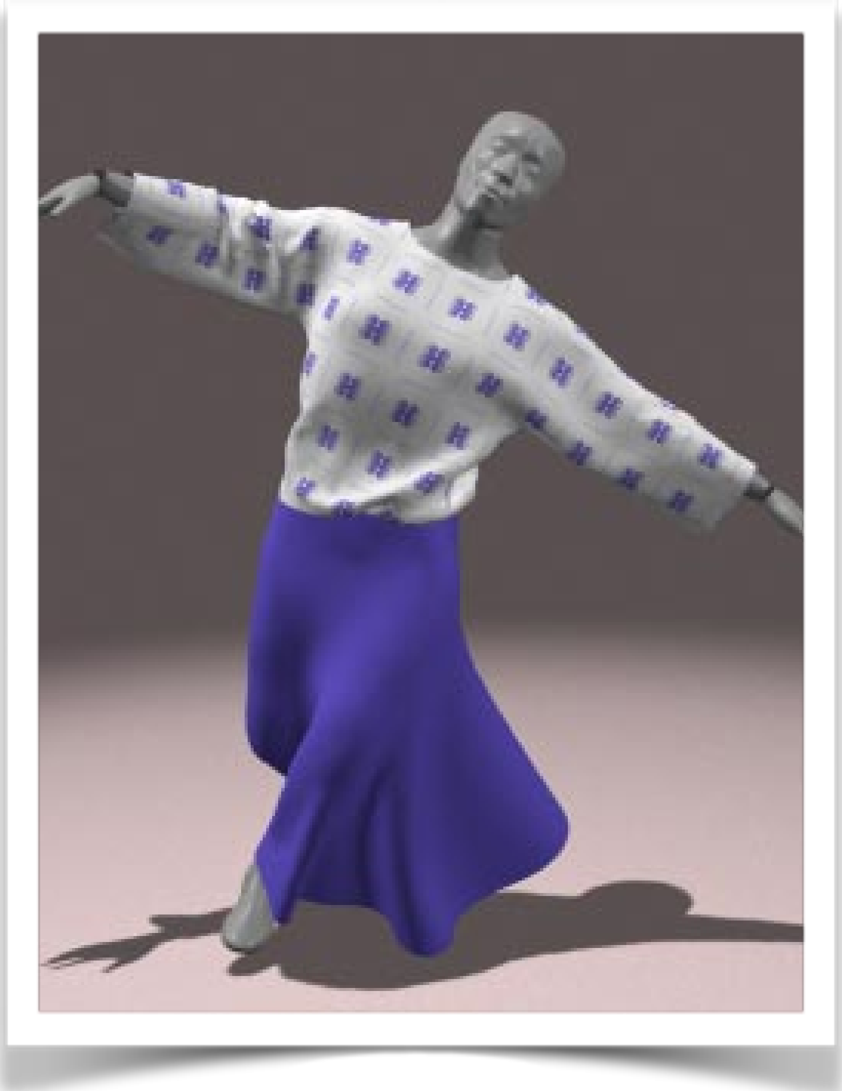

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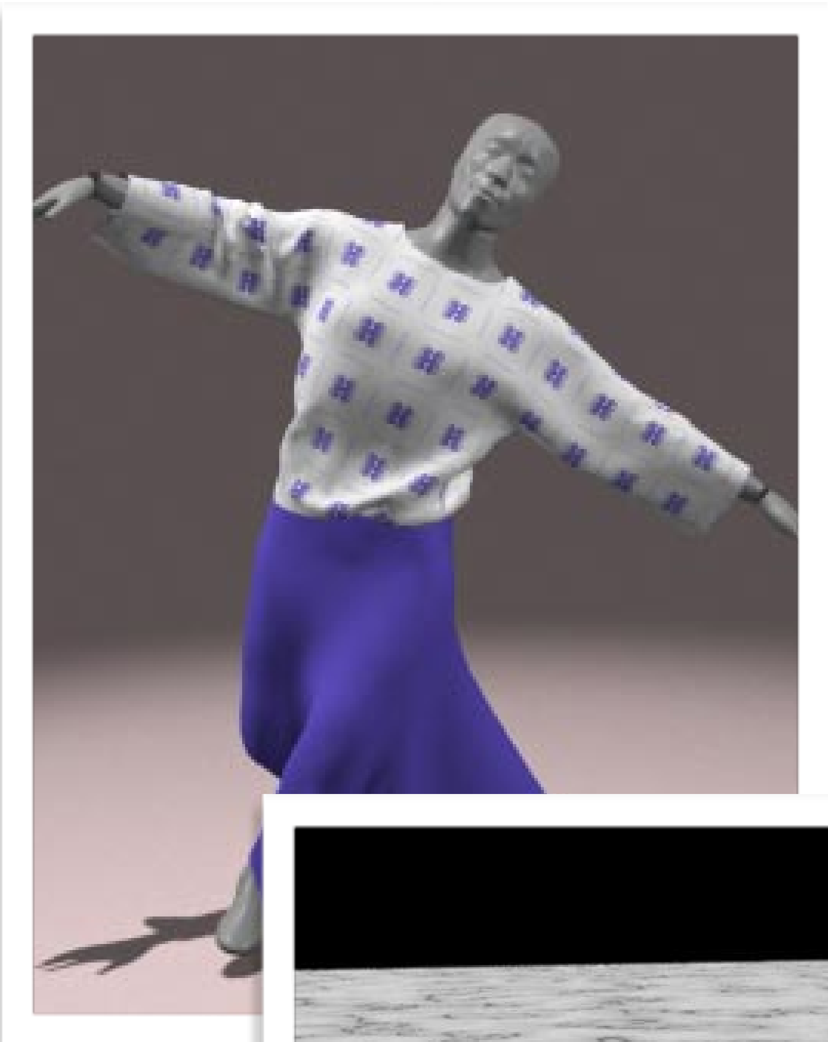

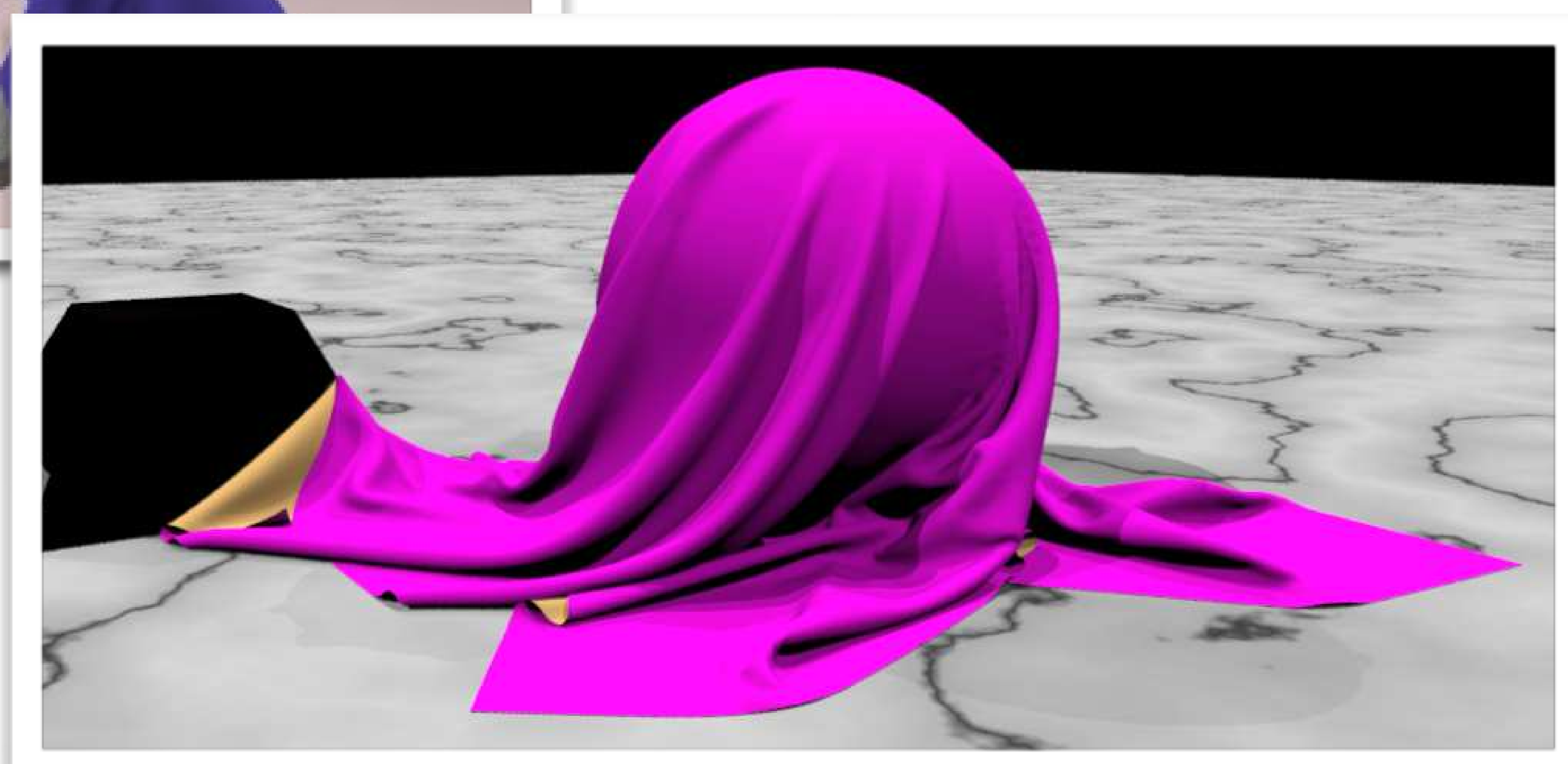

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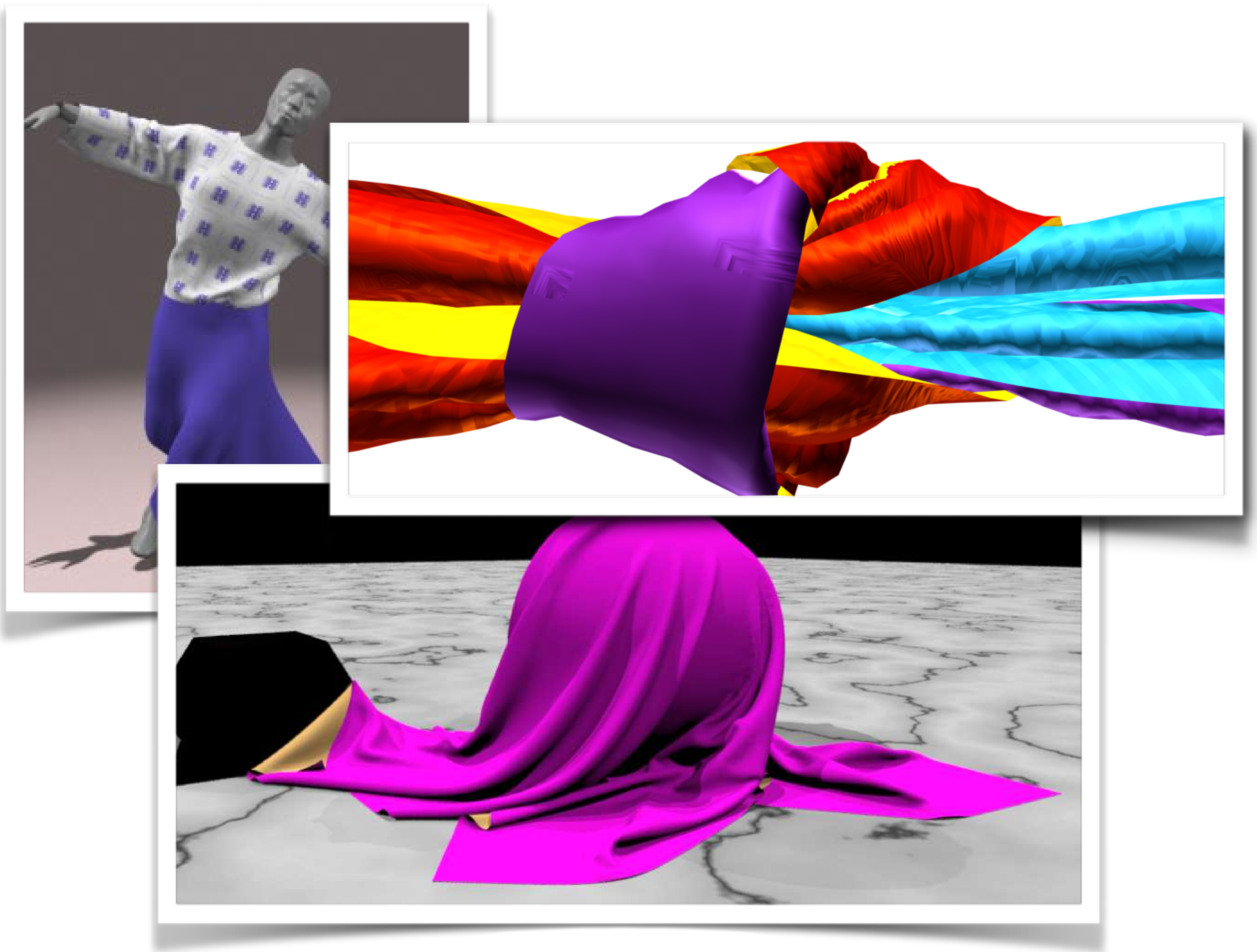

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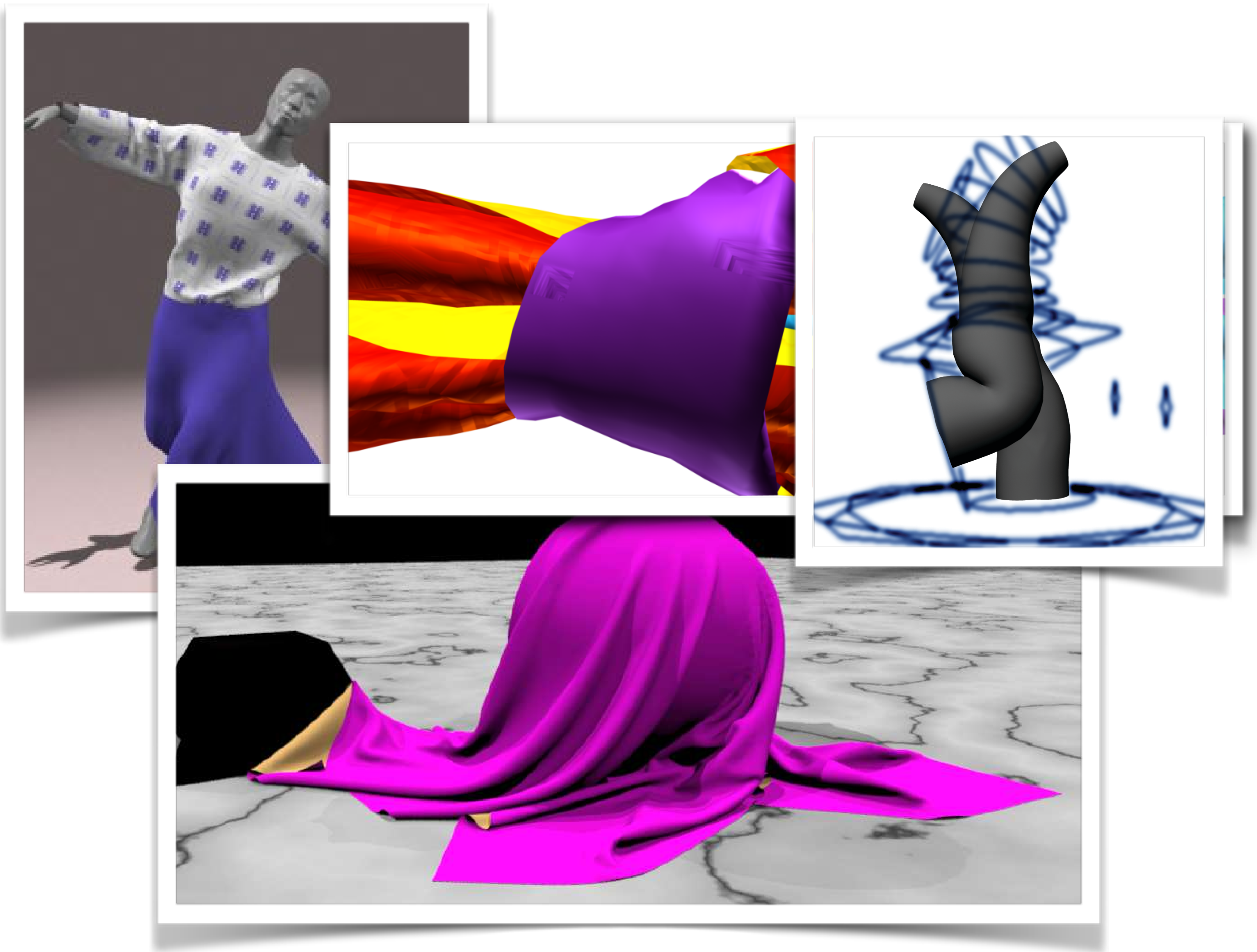

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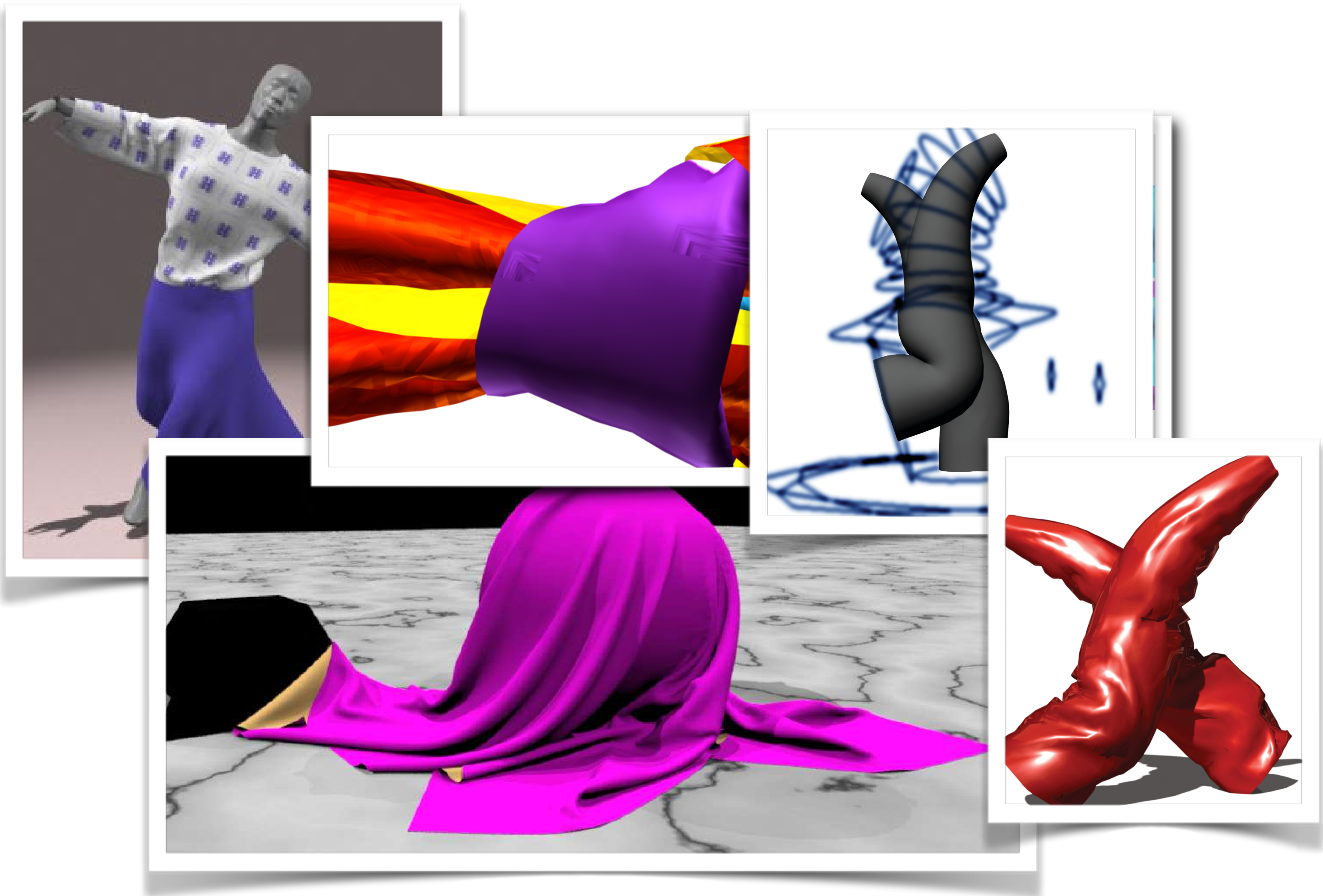

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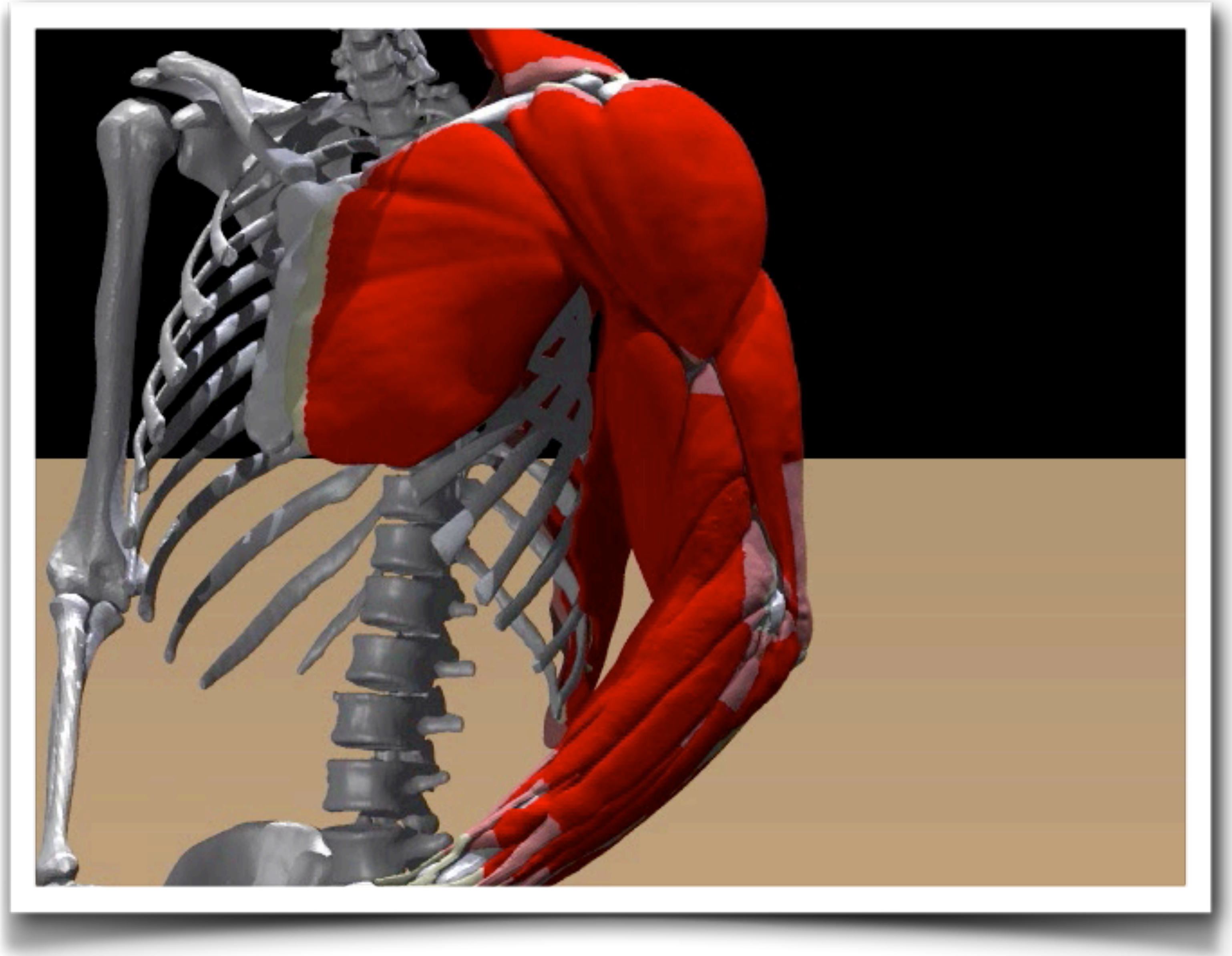

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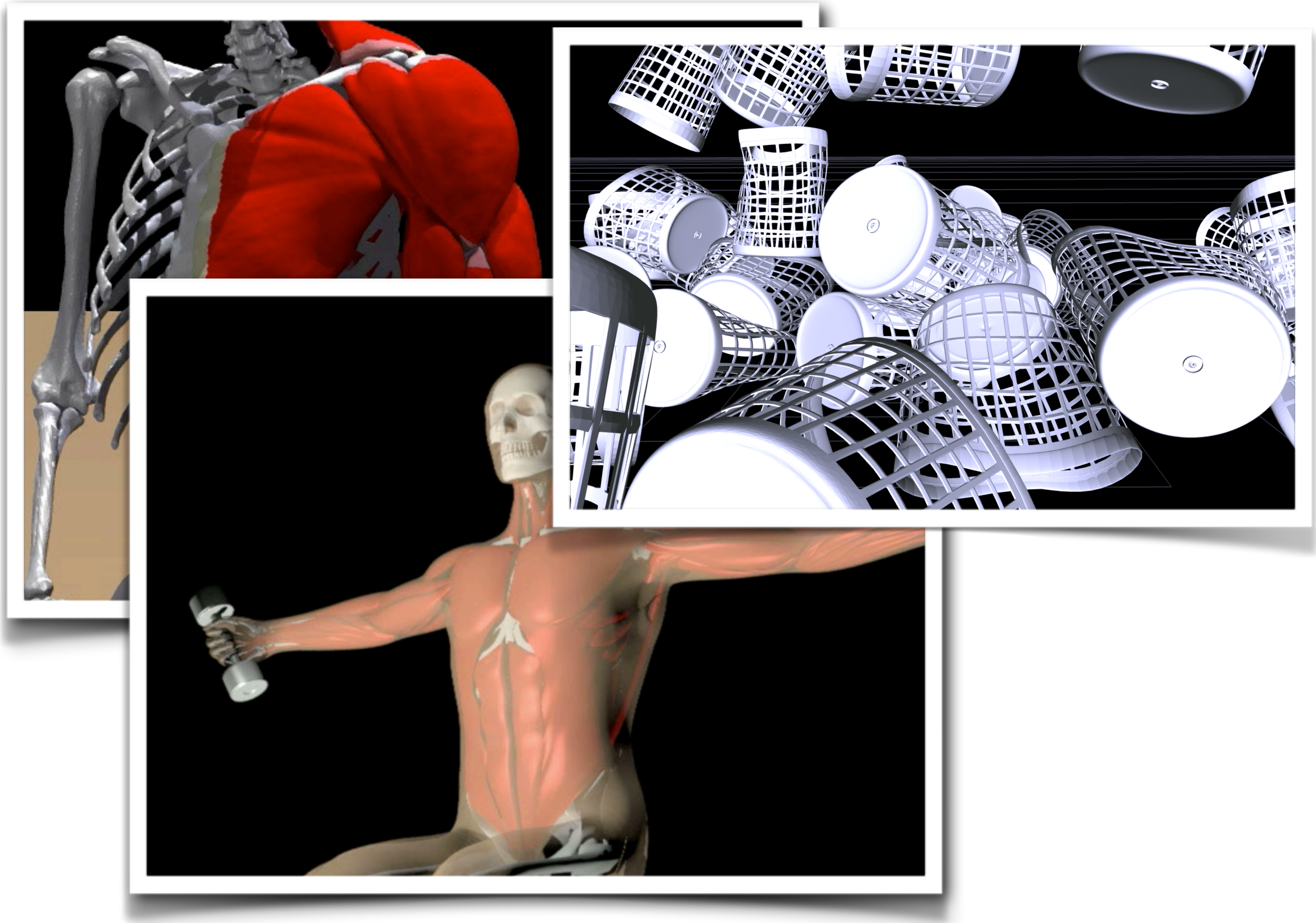

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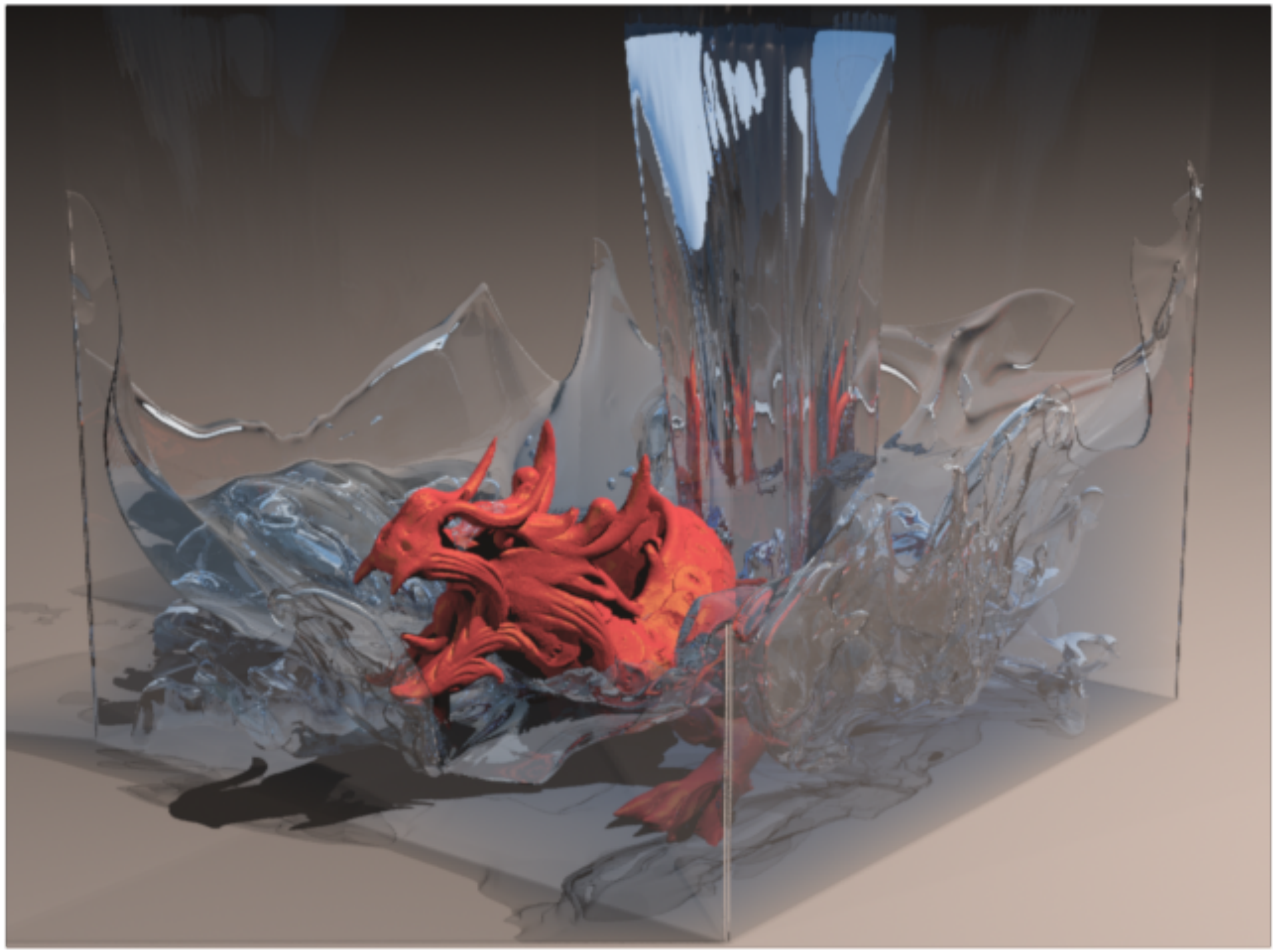

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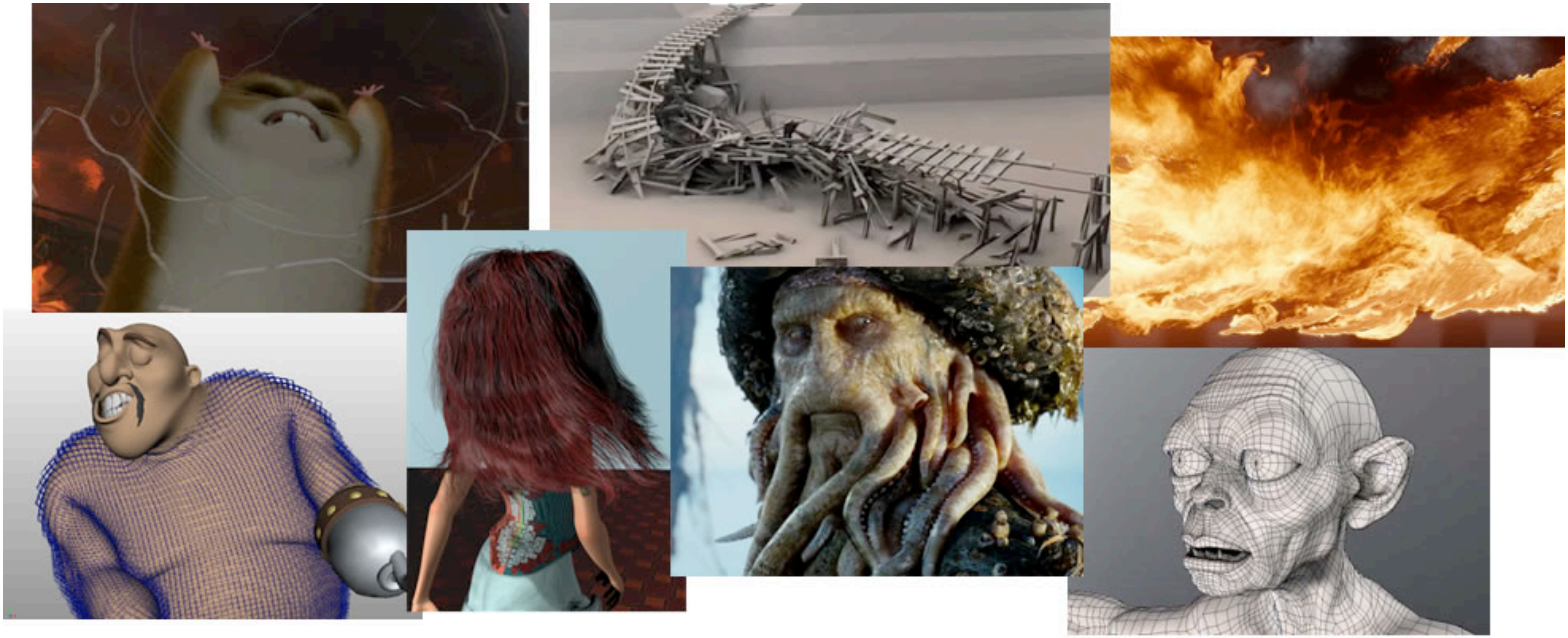

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